AN INVESTIGATION OF FACTORS AFFECTING CURRICULUM IN AIR POLLUTION TECHNOLOGY PROGRAMS

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A list consisting of 104 topics, concepts, equipment types and analyses pertaining to the technology of air pollution control was constructed. A graduated scale of importance for all items was devised and incorporated into the list. The list was then sent to 208 municipal, state and federal air pollution control agencies, including six in Canada. The list (questionnaire) was also sent to 218 representative private industrial and consulting engineering firms. The firms and agencies were asked to assign to each topic a grade indicating its degree of importance for an air pollution control technician. Usable responses were received from 169 government control agencies and 77 private firms for an overall rate of 57.7%. An overall weighted average grade was calculated for each of the 104 topic items and they were then ranked by category. An overall ranking for all items from all respondent groups was also prepared.

The Delphi technique was used to estimate the content of air pollution control technician programs of the future. A panel of 40 experts in the air pollution control field was selected. These experts were asked to predict future developments in the air pollution control field along with the expected earliest and latest dates for the realization of each event. The individual events were tabulated and classified. Three rounds of questioning were conducted. The final list of events was arranged chronologically in the order of expected occurrence.

Results of the technician questionnaire indicated that government agencies recognized priorities in training programs much different from those of private firms. Also, the Delphi project indicated that technician training programs of the future will need to be much more heavily oriented toward instrumentation and automatic/remote measurement and monitoring methods.

CHAPTER 1

INTRODUCTION

The growth of widespread public awareness of, and concern for, a degraded natural environment was largely a product of the turbulent '60s in the United States. This decade saw the recognition of a number of social problems - problems which had existed for a long time and needed only special circumstances to attract wide attention. Practices of business and industry, and of private individuals, which had traditionally been taken for granted, now become topics of heated discussions between citizen groups concerned with a moderate approach to the use and development of natural resources and those interests which desired to retain the older "laissez-faire," strictly profit motive. Steadily deteriorating environmental conditions and a steadily increasing population led to greater public involvement, which promoted legislative action at all levels of government. Local smoke control ordinances date back to the beginning of the 20th century, but enforcement programs were rare and generally ineffective. The first federal legislation dealing with air pollution was passed in 1955. This act, which was concerned primarily with research and support activities, was followed in the '60s by several laws strengthening the role of the federal government in controlling air pollution emissions. Air pollution control laws, ordinances and regulations passed by local, state and federal government have resulted in greatly increased research, surveillance and control activities. The

role of the federal government has greatly expanded since the original 1955 law. It is now the primary authority for air pollution control in the United States, charged with enforcing a wide array of regulations pertaining to the discharge of pollutants into the air. The increase in interest in controlling air pollution emissions from all sources has resulted in an upsurge in the demand for trained technical manpower. Educational institutions have responded to this stimulus by offering training programs from the technician level through the Ph.D. degree (8).

Formal training in the field of air pollution control is marked by great diversity. Thus, courses treating various aspects of air pollution are offered by four-year colleges and universities, community colleges and technical institutes, area vocational and trade schools as well as by professional organizations such as the Air Pollution Control Association, American Public Health Association, American Industrial Health Association, and others. Training is also carried on by government agencies such as the U. S. Public Health Service, the Environmental Protection Agency and the National Institutes of Health. Diversity of discipline is demonstrated by the range of fields concerned with the different aspects of air pollution: meteorology, botany, veterinary science, human health and medicine, law, physics, chemistry, various fields of engineering such as environmental, chemical, civil, automotive, nuclear and mechanical, and others. Technician training has been accomplished via short courses by the organizations noted above, on-the-job training by government and private industry and formal training programs offered at community colleges and technical institutes.

The federal government long played an important role in the training, at various educational levels, of air pollution control

personnel. The support offered by the government was of several types: first, research grants were awarded to colleges and universities for specific projects in air pollution control and related topics; second, stipend grants were awarded to certain college students enrolled in approved training programs to ensure a supply of highly trained technical personnel; and third, short courses dealing with various topics in air pollution control and technology were offered gratis to qualified government and industrial employees by the staff of the U. S. Environmental Protection Agency (33). In the early 1970s, the federal government began to reduce this support, with adverse effects on the total problems of research and the training of personnel. Research grants were greatly curtailed, training program support reduced, or entirely eliminated, and user fees charged at the short courses offered by the U. S. Environmental Protection Agency. Moeller discussed these problems, and their consequences, in his paper, "The Crisis in Air Pollution Manpower Development." Citing these cutbacks in the funding of training programs and sponsored research, Moeller said, "short term technical training is being hampered by policies such as the assessment of user charges, and the need for qualified technicians... is being almost totally neglected" (19).

Statement of the Problem

Since the first two-year technician training program in air pollution technology was begun in 1968, approximately a half-dozen others have been attempted. Some of these programs have been oriented toward a specialization in air pollution control while others have presented more generalized curriculums in environmental control technology. In these latter programs, air pollution control has comprised only a part of the specialized training.

As of this writing, there has been no known attempt to define nationwide minimum training levels for air pollution control technicians. That their training encompasses many fields and concepts is well established, but the problem of setting a reasonable and generally accepted limit to their competence has not been addressed.

This study attempted to establish a basic set of concepts or areas of competence generally accepted by the air pollution control community as appropriate to a two-year college level program for training air pollution control technicians. Also, an attempt was made to determine the content of future technician training programs.

A two-pronged approach to this problem was used. First, in order to evaluate present curriculum content of technician training programs, the opinions of persons directly connected with air pollution control activities were sought as to the knowledge and concepts they felt were essential to a well-trained air pollution control technician. In this approach, two groups were contacted; heads of government air pollution control agencies (2), and heads of pollution control departments in selected private firms.

The second approach to the problem consisted of a modified Delphi project to determine the probable content of future technician training programs. In this part of the study, the Delphi panel consisted of those persons who acted as an advisory committee during the preparation of a curriculum guide for two-year air pollution technician training programs. This third group subsequently was enlarged, using criteria discussed later, to provide a larger group for the Delphi portion of the study.

Purposes of the Study

1. To list and evaluate those areas of knowledge or competencies that an air pollution control technician should possess as judged by experts in the air pollution control community.

2. To determine the probable content of technician training programs of the future.

Limitations

The limitations of this survey were directly related to those inherent in the survey-type research project. Within these imposed limitations, the survey technique can provide useful information to the design of curriculum in air pollution technology training programs. For example, a mail-out survey generally will not result in responses from each subject in the sample.

There has been some disagreement among educational and social science researchers as to whether surveys are so statistically constituted that they are capable of being used to test hypotheses. Guba (14) said emphatically that surveys cannot be so used. On the other hand, Kerlinger stated, "Most research in education is done with relatively small non-random samples. If hypotheses are supported, they can later be tested with random samples of populations and if again supported, these results can be generalized.... In other words, survey research can be used to test hypotheses already tested in more limited situations, with the result that external validity is increased" (16, p. 406).

In Guba's typology, this project would be classified as a survey. Thus, it can possess external validity. That is, the survey may be valid for answering questions proposed in the study. However, internal validity (controlling & estimating experimental variance) is not applicable

in a project as described here. As defined by Guba, "attempts to study causal relationships or to test hypotheses utilizing surveys are entirely erroneous." However, "in order to establish norms for a group, or in order to describe the parameters of a population...the survey is entirely adequate" (14). Accordingly, the survey as described herein could be quite useful in describing those elements which should be universally present in technician training programs in air pollution technology, and thus possess a high degree of external validity. Internal validity, being determined by the degree of control over experimental variance, is not applicable to this project, and as maintained by Guba, cannot be used to determine causal relationships or to test hypotheses.

Delimitations of the project involved the sources of data used. Three major sources were used: those government control agencies which employed two or more technicians, and numbered approximately 192; and representative industries selected by the magnitude of contribution to the total air pollutant emissions in the U. S. as described in the section titled Instrumentation and Sampling for Technician Curriculum. The third source of data (for the modified Delphi project) consisted of the advisory committee members who served for the preparation of the USOE publication Air Pollution Technology: A Suggested Two-Year Post High School Curriculum. The latter category numbered 12 individuals, but the membership of this third group was augmented as described later.

Assumptions

There were several assumptions inherent in a survey such as the one described herein. The first had to do with the topic items included in the list of tasks and concepts used. The assumption was that all of the more important tasks and concepts were included in the list. Safeguards

against an inadvertant omission were used. The list of topic items was reviewed for completeness by several of the writer's professional colleagues. Also, the questionnaire included a category for "other important tasks" to which the respondent could add items of his own.

The second major assumption in the survey was that the respondents were the best qualified persons to judge the competencies a well-trained air pollution control technician should have. Though this was a subjective question, the people contacted were professionally involved in air pollution control activities and should have been in an excellent position to judge.

Third, it was assumed that the respondents recorded their honest opinions and that each individual item was evaluated independently of all others. This was a critical assumption. Very often, the director of a governmental or industrial air pollution testing and control program is an individual who has great demands on his time. It was possible that this individual, in his desire to complete the questionnaire quickly, would traverse the entire list, assigning a rating of five to each task/concept. This "halo effect" would have nullified the results of the survey and invalidated any conclusions pertaining to the development of the curriculum topics in air pollution control technology. Therefore, it was assumed that respondents who completed and returned the questionnaire rated each item individually.

Fourth, it was assumed that the Delphi technique provided as reliable a projection of the future of technician training as is possible to obtain.

Definition of terms

1. Air Pollution Technology: A two-year post high school Associate Degree training program to train technicians to work in air pollution control activities.

2. Technician: A person who is a graduate of a two-year post high school technical program who works with or in support of engineering or scientific personnel, or in a semi-independent situation. This individual has competence in the basic science and/or engineering areas and is capable of performing complex technical tasks in his area of training with a minimum of supervision.

3. Occupational Education: Those educational programs which are usually conducted at a post high school level and are two years in length. These programs usually terminate with an Associate Degree and a job, and in that sense, are "non-transfer" programs.

4. Pollution Control Agency: A governmental agency, usually at the local or state level, charged with the enforcement of local, state and federal laws regulating the emission of atmospheric pollutants from man-made sources. These agencies are often responsible also for the enforcement of public drinking water purity tests, enforcement of water pollution regulations, food handling and other public sanitation laws.

5. Private Industry: Any privately controlled and operated company in business to make a profit. This can be a firm engaged in the manufacture of goods, or one which provides services, such as an engineering consulting firm.

Instrumentation and Sampling for Technician Curriculum

Data for the technician curriculum design were obtained by means of questionnaires. These questionnaires contained a list of tasks, concepts,

analyses, equipment types, and other information which were related to the air pollution control field. The respondent was asked to rate each item as it applied to his organization. Any one of four possible ratings was assigned depending on the importance of the item. A list of these questionnaire items, along with the cover letter and instructions, is presented in Appendix A.

A rating of five indicated that the item was of critical importance (a technician must be knowledgeable or proficient in the area): the student must demonstrate in training that he can perform the skill or job at the appropriate level of accuracy and speed for satisfactory performance on the job. Assignment of the number three to an item indicated a task which the respondent felt was fairly important, but not absolutely essential: the student must demonstrate in training that he can perform the skill or job correctly, although not with the speed or accuracy required on the job. A rating of one indicated an area of low importance (a task or analysis performed only infrequently by that organization): the skill or job should be described or demonstrated to provide a picture of the job, but the student will not be expected to perform the skill or job upon completion of training. A test or concept not applicable or inappropriate to that organization was indicated in a column headed "N/A".

The data collection instrument (questionnaire) was sent to two groups: governmental air pollution control agencies and representative private industries.

As of the present writing, there were active full-time air pollution control staffs in 48 of the 50 states (only Alaska and Wyoming did not have full-time staffs), plus Puerto Rico and the District of Columbia.

In addition, there were active control programs in 170 municipalities or counties for a total of 225 state and local air pollution control agencies with full-time staffs. Not all of these agencies employed full-time air pollution control technicians. Therefore, questionnaires were only sent to those agencies which employed two or more full-time technicians. Of the 225 agencies mentioned, 192 fell into this category and were contacted. Also, questionnaires were sent to the 10 regional administrators of the U. S. Environmental Protection Agency and six active government control agencies in Canada. Thus, 208 questionnaires were sent to government control agencies (2). A list of all government agencies contacted is presented in Appendix B.

In sampling the private sector, the following selection procedure was used: the 20 largest industrial source categories of air pollution in the United States have been reported by manufacturing category by the U. S. Environmental Protection Agency (6). A tabulation of these major source categories is presented in Appendix C. Approximately 10 of the largest companies in the 20 major manufacturing categories were selected from Standard and Poor's Register of Corporations, Directors and Executives (29). Several of the manufacturing categories did not list 10 individual companies; thus, the final list contained 197 firms.

Another significant area of the private sector is the field of engineering and scientific consulting firms. These firms are composed of individuals who perform appropriate consulting services for private industrial firms. The Journal of the Air Pollution Control Association annually lists those firms which have expertise in the field of air pollution control and monitoring problems. In this listing, the Journal divided the United States into four areas: Western States, Midwestern

States, Southeast and Gulf States and Northeast States. In 1973, 209 consulting firms were listed under these areas (7). A stratified random sample of the firms was taken such that approximately 10% of the firms in each geographic area were contacted. This resulted in a list of 21 consulting firms which, when added to the 197 industrial firms mentioned earlier, gave a total private sector list of 218 companies and firms. A list of all the private firms contacted is presented in Appendix D.

Completed questionnaires were examined by comparing the weight given to the same item by the different respondent groups. The weighted rank average for each item was calculated for each group. From this information, an overall weighted average was calculated to evaluate the relative or rank order importance for each item to be compared with all other items on the list.

Delphi Projections for Future Curriculum Developments

A modified Delphi project was conducted to obtain expert opinion as to the content of technician training programs in the future. The Delphi technique has been used in several different applications and utilized the opinions of experts in a specific area to predict developments which can be expected in the future (15). The method used was as follows: a list of specific future developments which could be expected in the field of air pollution control and monitoring was requested from a panel of experts in the air pollution control field. The developments pertained to advances or changes in the air pollution control field which might have an effect on the status of air pollution control and monitoring activities. These requests for assistance were sent to 40 individuals (1). Of the 40, 12 had previously served on the advisory committee of

the publication Air Pollution Technology: A Suggested Two-Year Post High School Curriculum. The remaining 28 were selected by applying the following criteria: (1) past presidents of the Air Pollution Control Association (APCA); (2) members of the Board of Directors of the APCA, (3) membership on committees of the APCA, and (4) publications in the air pollution control field. A copy of the letter inviting the recipient to participate in the modified Delphi project, along with appropriate instructions, is contained in Appendix E.

For each projected development, the panel members were requested to estimate the earliest and latest times they felt the particular event might be realized.

The individual lists were collected and tabulated for specific items and the earliest, latest and median dates for the realization of each item were determined. The composite list was prepared, grouping specific topic items into three broad categories: Air Quality Measuring/Monitoring, Air Quality Regulations/Control and General Energy/Environment. Median earliest and latest dates, as well as an overall median date for each item were determined. The composite list was then returned to the panel members with a request that they review the tabulation and again enter the earliest and latest dates expected for the realization of each item, along with any reasons for changes in the dates. The results of the second round were tabulated, new medians noted and returned to the panel for the third and final round. On the last round, panel members were again asked to revise their earlier estimates if they so desired, and invited to note the reasons given for any changes in earliest and latest dates for each item. The completed third round was then examined for earliest, latest and median dates, and

degree of consensus was estimated by calculating interquartile ranges.

The advantages claimed for the Delphi technique are several. First, the panel can be interviewed by mail, thus saving considerable expense by not requiring the participants to be geographically together. Second, pressure to conform is reduced due to the anonymity of each respondent to the others. Third, each panel member, by seeing the reasons advanced by the panel members for dating events can modify his own estimate to reflect conditions or parameters he may have overlooked previously. Finally, the Delphi technique provides a vehicle whereby a group of people expert in a particular subject area can make predictions as to what developments can be reasonably expected for that area in the future. The purpose of using the Delphi technique was to attempt to identify a number of specific future developments which were expected to take place in the air pollution control field, and to estimate the date each event could be expected, by a group of experts in that field (24).

Format of the Study

In Chapter 1, an introduction, statement of the problem and general approach have been presented. Also, purposes, limitations and assumptions have been discussed. The general design, sources of data, instrumentation and treatment of data have been described.

Chapter 2 is a review of the pertinent literature. This chapter describes curriculum design in post high school technical education programs and the history and growth of training programs for air pollution control technicians.

A presentation of results obtained from the study is contained in Chapter 3. This chapter is divided into two major parts: the results of

the technician questionnaire, and the Delphi projections.

Chapter 4, a general discussion of the data, is also divided into two parts, corresponding to the two major areas covered by the study.

Finally, Chapter 5 presents a summary of the entire project and attempts to relate the results obtained to the stated purposes of the study outlined in Chapter 1.

CHAPTER 2

REVIEW OF LITERATURE

This section will be concerned with two main facets. The first area is the state of curriculum design efforts in post high school technical education programs. The second is the history, growth and present state of training activities for technicians in air pollution control work.

Technical Education Curriculum Design

That curriculums in occupational education should be based on occupational analyses appears to be held by many, but not all educators. A publication of the Division of Vocational Education of U.C.L.A. listed seven standards for curriculum development in vocational-technical education. Number two stated,"Development of curriculums must be based upon occupational analyses and on preparation for entry into the labor market and/or successful advancement in employment on a career-ladder basis" (9).

Lewis discussed developments in the use of "zoned analysis" as first proposed by Larson and Blake in 1969. According to these writers, "a realistic, functional curriculum depends upon an understanding of the needs and requirements of the occupational field. Determination of the elements of the occupation (the skills, knowledge, habits and attitudes essential to employment) demands an occupational analysis." Further, Lewis quoted Roney as saying,"occupational education is based upon the

premise that the factors contributing to success in an occupation are relatively well known and can be converted into certain educational experiences" (17).

In defining the term, Lewis said,"Zoned analysis proceeds from the general to the specific. This technique will aid the developer in preparing curricula for various employment levels within an occupation or in preparing a total curriculum which employs the 'ladder concept'."

In the case of new or emerging occupations (such as Air Pollution Control Technology) there must be close cooperation between educators and persons working in the occupation. Since most occupational innovations are learned in an on-the-job basis at first, there needs to be a communication network with field personnel to constantly monitor changes in the occupation (17).

In evaluating curriculum materials, Popham said, "The most defensible criterion by which to judge the adequacy of curriculum materials is the degree to which those materials, if used as directed, can consistently bring about desired changes in the behavior of the intended learners." This writer also strongly urged the use of the "criterion referenced" (or ends-oriented) approach as opposed to means oriented (or "how" it is taught) approach to curriculum evaluation. Popham listed five key ingredients of properly stated instructional objectives:

1. They must be student oriented.
2. They must involve specified, measurable terminal behavior.
3. They must indicate conditions under which behavior is to operate.
4. They must include criterion measurement by which success or failure of having achieved the desired terminal behavior can be judged.

5. Objectives should be specific. Occupational analysis should be used to make the objective specific.(26)

Agreeing with Popham, Shoemaker cited five guidelines to follow in designing curriculums and curriculum materials:

1. Preparation for initial job entry is basic responsibility of public educational programs.
2. These programs should be goal centered.
3. Curriculum changes are necessary to maintain relevancy to social and economic conditions.
4. The use of core curriculums based on occupational goals should provide preparation for employment and future participation in society.
5. The curriculum is concerned with knowledge and skills; but also, the total education, economic, social and physical needs of the student.(27)

Shoemaker also listed 11 specific areas which job analyses should provide information for curriculum design:

a. work units, jobs or operations
b. skills and work practices
c. safe practices and safety precautions
d. equipment, tools and materials
e. applied mathematics as related to the job
f. applied science as related to the job
g. specification and blueprint interpretations
h. occupational information and terminology
i. work habits and attitudes
j. personal relationships - job related
k. physical capabilities required.(27)

Taking exception to the use of the occupational survey as espoused by the previous writers, Gillie argued that the method has at least two

critical disadvantages. The first is that the job being analyzed is not necessarily the one to which the graduate will go - jobs change constantly and curriculums tend to become obsolete. Second, there is danger in procuring expensive equipment which quickly becomes obsolete. Specific tasks using specific equipment should be taught by the company using the method at the time it is needed. Gillie felt the curriculum should be knowledge-based rather than skill-based and incorporate a high degree of flexibility in order to keep the graduate up-to-date with changing job requirements (12).

Chapter 3 of Gillie's work was an interesting account of a curriculum design project employing his own approach to this problem. The project, which constituted that author's doctoral dissertation, involved the design of a two-year electronics technology program for use in a community college.

Gillie first established a set of criteria for identifying nationally known educators and industrialists in the electronics field. Using these criteria, he identified ten electronics experts whom he contacted and requested assistance. These experts were asked to prepare a list of topics they felt were most pertinent to the education of electronics technicians. From these responses, a questionnaire was constructed containing 72 items. No item was included unless it had appeared in the lists of at least three of the experts. The questionnaire requested that the respondent rate each item two different ways: on a scale of relative importance from zero to three, the respondent was asked to first rate the importance of the item in training electronics technicians today. Second, the respondent was asked to rate the importance of the item to the technician of ten years from now. The questionnaire was then sent

to 184 heads of electronic technology programs in community colleges or technical institutes and 167 heads of technical personnel in selected electronics industries.

Gillie called this type of forward-looking projection as the "crystal-ball" approach as opposed to the occupational survey or "rear-view mirror" approach. He felt that "predictive curriculum planning... can be a successful technique for identification of curriculum content.... The approach does have some hazards; the key to successful implementation of this method lies in great part with the competence of the crystal ball gazers"(12).

Using rank order coefficients, t-tests and other appropriate statistical methods, Gillie was able to ascertain those topics judged to be important to educators and industrialists <u>today</u> and the extent to which the two groups agreed. He then determined the same information for technicians of <u>ten years from now</u>, and finally a determination of those topics held to be important <u>now</u> but <u>not ten years from now</u>.

<u>Air Pollution Control Technology</u>

The widespread publicity given to the problems concerning the environment has resulted in corrective legislation at all levels of government. New laws in turn focused attention on the need for trained technical manpower.

As noted previously, training activities in the field of air pollution control have developed along several lines. At the baccalaureate and post-baccalaureate levels, colleges of engineering have long offered a degree in civil engineering or "sanitary" engineering. This degree covered various topic areas, one of which was the design, construction and operation of water and wastewater

treatment facilities. Other departments which offered courses or degrees in this field were chemical and mechanical engineering, as well as schools of public health. In the latter, the emphasis was placed on health aspects (such as milk and food inspection, rodent and insect control and general sanitation) rather than on engineering.

Chemical and mechanical engineering curriculums have been concerned with gas flow and chemical recovery in combustion and chemical process equipment. Thus, during the increased public awareness of the critical problems facing the environment which occurred during the '60s, these departments served as starting points for the formation of new "environmental engineering" and "environmental health" programs in colleges and universities throughout the U.S.

The development of training programs at the technician level has been marked by as much diversity as that shown by baccalaureate and advanced degree programs. Some of the training models suggested, tried or in existence include one-year post high school vocational programs, two-year environmental science programs (aimed primarily toward "health" aspects), two-year environmental engineering programs (aimed more at engineering technician education), and air pollution technology options "grafted" into existing two-year chemical technology programs. In the environmental science or technology programs, air pollution control technology comprises only one area of a broad exposure to disciplines such as solid waste disposal, water and wastewater treatment, public health and sanitation, radiological health and others. These broad-based programs generally offer only one or two courses in air pollution technology.

Among some of the innovative programs which deal primarily with the training of air pollution control technicians are programs in which the student receives all his air pollution specialty work during the last term in school, and programs in which this specialized work is received during the second, or final year. There are other programs in which all the specialized air pollution technology courses are taught during the first year, with the second year being devoted to mathematics and basic sciences such as biology, chemistry and physics.

An example of an existing program modified to prepare technicians to work in the field of air pollution control was reported by Painter (23). Fayetteville Technical Institute began offering a two year Associate Degree program in water/wastewater technology in 1964. In 1969 two courses in air pollution control were added to the curriculum. With several other revisions, the name of the program was changed to Environmental Engineering Technology.

Sullivan County Community College in South Fallsburg, New York, offered a technician training program in air pollution and wastewater technology. The unusual aspect of this program was that all the specialized pollution technology courses were taught the first year. If the student desired to obtain employment after the first year, he was awarded a diploma. The student also had the option of continuing his studies for a second year, after which he was awarded an Associate Degree (30).

Somewhat similar to the Sullivan program was one titled Retro offered by Brevard Community College in Cocoa, Florida (4). This program offered both air and water pollution control training and was originally designed to retrain aerospace technical personnel who had

lost their jobs at Cape Kennedy Space Center. The program was funded by the Department of Labor under the Manpower Development and Training Act (MDTA) but was subsequently broadened into a full two-year Associate Degree technician training curriculum. The student could receive training for 26 weeks to obtain employment skills in the case of aerospace workers, or could complete the normal two-year course in the case of regular students who wished to receive a degree.

It was not until October, 1968 that the first two-year Associate Degree program specifically designed to train air pollution control technicians was begun. This program was discussed by Turner (31). As originally implemented, the program consisted of 75 semester hours distributed as follows:

Area	Semester Hours
Social studies, humanities, english, etc.	18
Math, biology, chemistry, physics	22
Air pollution technology	21
Electives	14
Total	75

Program modifications since the original curriculum was instituted were discussed by Turner in a subsequent paper. The major changes were the inclusion of an introductory water pollution technology course and an air pollution seminar in which visiting lecturers could present information on a variety of environmental topics. The two-year degree awarded was changed from the Associate in Arts to the Associate in Science. This had the effect of allowing more technical hours to be added to the curriculum, as well as facilitating transfer for program graduates to Bachelor of Engineering Technology programs. The Bachelor of Engineer-

ing Technology degree was a relatively new program area which has been offered by engineering colleges more and more commonly in recent years.

Other program changes contemplated by the College were the combination of several of the basic air pollution technology courses so that new courses in instrumentation, solid waste management and others could be added. As described by Turner, recruitment, not job placement, was the greatest single problem facing the program (32).

Santa Fe was selected by the U. S. Office of Education to prepare a curriculum guide for two-year post secondary air pollution technology training programs. The guide, one of series sponsored by USOE for various technician occupations, was designed to serve as a national model for this kind of training program (3).

Oregon Technical Institute in Klamath Falls, Oregon offered both two-year Associate and four-year Bachelor of Technology degree programs. A two-year Associate Degree program called Environmental Health Technology included a second year option in Air Quality Control (22). Four courses in air quality measurement and control were included in the curriculum.

Other colleges which had recently begun Associate Degree programs in air pollution control technology were Genesee Community College in Flint, Michigan (11) and Muskingum Area Technical College in Zanesville, Ohio (20).

Brown and Greninger described the Air Pollution Control Technology program at Pennsylvania State University (5). This was a two-year Associate Degree program initiated in September, 1970. Several aspects of the project are worth noting. First, although the curriculum consisted of six 10-week terms, the first five were taken at the Berks

Campus, located over 100 miles from the main University campus. These five terms were devoted to basic sciences and general education. The final term was spent at the main University campus at the University Park, Pennsylvania. It was during this term that the student received his entire air pollution control technology training.

The second unusual aspect of the curriculum was that there were three specialty areas available to the student within the air pollution control field: air monitors, compliance-section technicians and engineering section technicians.

A breakdown of the curriculum revealed the following structure:

Area	Semester Hours
Communications	9
Mathematics	10
Chemistry	11
Electricity-Electronics	13
Environmental Engineering & Science	13
General Engineering and Applied Physics	11
Total	67

This appeared to be a strong program; however, it would be interesting for an evaluation to be made of the effect, if any, of presenting all the special air pollution control courses the final term of the curriculum. A comparison of this curriculum with the Santa Fe curriculum described previously revealed that environmental engineering and science courses comprised 13 of 67 hours at Pennsylvania State, while air pollution technology courses accounted for 21 of 75 total hours at Santa Fe, or approximately 19% and 28% of the total curriculums, respectively. Near the end of the article, in a paragraph referring to manpower demands

for air pollution control technicians, the prediction was made that by 1975, "An estimated 1.5 million technicians will be needed to fulfill the demands created by our industrial growth" (5). No reference or source for this figure was given, which contrasted with projections made by others. For example, Fanning estimated that by 1975, 138,000 environmental technicians will be needed (10). Included in Fanning's environmental technician classification are several sub-categories such as sanitarian technician, environmental engineering technician (which includes air pollution control technicians) and radiological health technician. By 1980, Fanning predicted that 198,000 environmental technicians will be required. Using a similar definition for the classification environmental technician, Graber, Erickson and Parsons projected manpower requirements to 1980 and concluded that 214,000 environmental technicians will be needed (13).

In June 1970, the Secretary of Health, Education and Welfare sent to Congress and the President a report prepared by the National Air Pollution Control Administration titled "Manpower and Training Needs for Air Pollution Control"(21). Using statistical predictive techniques, the report projected manpower requirements to 1974, based on pollution control agency staffing for 1969. An estimate of industrial needs for control technicians for 1974 was also included. The total number of air pollution control technicians needed was predicted as slightly more than 8,000 for 1974. Of this total, it was estimated that 1,000 technicians would be working in the state and local government air pollution control agencies, 660 working for the federal government and the remaining 6,340 working for private industry.

The United States Environmental Protection Agency conducted a

manpower survey of state and local air pollution control agencies in April, 1971 (34). In all, 264 agencies were surveyed which included both full-time and part-time staffs. At the time the survey was conducted, 28.9% of all agency positions consisted of technician-level jobs. These jobs were classified in the report as Technician I, II, III and Inspector I, II, and III. Assuming that the staff personnel distributions would remain constant, the manpower projections for 1974 and 1975 for these technician positions were 2040 and 2100, respectively. This assumption was probably conservative, since it could be argued that technician positions would probably be slightly higher, percentage-wise, in the total staff structure if expansion continued (34).

Two other pertinent literature references, one dealing with a Delphi projection and the other a general look into the future of air pollution control efforts, will be discussed briefly.

In December, 1972, the publication Long Range Planning published a paper titled "Energy and the Environment - A Delphi Forecast" by Smil.

The author's succinct and cogent description of the Delphi method bears repeating here:

> Delphi is a useful extension of systematic analysis into the areas of opinion and value judgments. It counters the limitations of traditional quantitative analysis, and opens up new horizons for more rational decision making. Evaluating probabilities and significance of various possible or desirable future developments, it offers new options for a planner. There appears to be hardly any other way to get these important, probabilistic yet definite answers. Respecting dissenting opinions, Delphi tries to arrive at a reasonable group consensus by iteration, but it is not just another kind of polling scheme...Delphi is not a decision tool - it is an analysis tool. Delphi output is still only an opinion, with no check for accuracy. There is no way to guarantee or control a specified outcome. It is an open-end analysis... Delphi's domain is intuitive forecasting. Its application is most useful and logical in complex areas where there exist uncertainity, doubt or disagreement, where there is seemingly

> no way to build any sort of model and where the results cannot be immediately confirmed or verified. (28)

In his study, Smil used an international panel of 40 scientists to forecast the possibilities/probabilities of a number of energy-environment related problems. One part of the project involved predicting the "probabilities of five environmental episodes involving energy industries-urban air pollution, power supply failure, jumbo tanker wreck, offshore drilling spill, nuclear radiation contamination...estimated for the 1970s" (28). The median probabilities of these five things happening, in order of highest to lowest, were severe urban air pollution episode, 90%; power failure over a widespread geographic area, 70%; wreck of a loaded jumbo oil tanker, 70%; serious oil spill from offshore drilling operation, 50%; and radioactive contamination of the environment caused by a nuclear power plant failure, 5%.

Another forecast area attacked by the panel was to rank in order of importance a number of environmental problems related to energy production and consumption. A total of 25 problems was elucidated by the panel. Of the top ten problems named, five were related to air pollution. Also, high on the list were water and thermal pollution, while aesthetic considerations such as aesthetic impact of dams and land use by power line right-of-way ranked lower in priority. The item ranked 25th was earthquake damage to nuclear power plants, "an opinion well justified by their past record of safety and impending improvements in protective systems technology," in the words of the author. This ranking, and the author's observation are quite at variance with the statements of Judge Sherwin, referred to later.

One final part of Smil's project will be mentioned here. The Delphi panelists compiled a list of 31 environmental protection, planning and management items in chronological order of their expected accomplishment. Thus, for item one, "Energy sources become the great pawn in international politics," the panel's median date was 1971. By 1980, the panel predicted the following: safe, large scale disposal of radioactive wastes, non-polluting internal combustion engine, abolition of growth for growth's sake concept, practical and economical methods of stack gas desulfurization, and effective, harmless control of accidental oil spills. By the year A.D. 2000, the panel predicted planned decrease of per capita energy demand and consumption, and effective population control. For the last item on the list, "no private powered cars allowed", the median date estimated by the panel was "never". Of special interest to the Delphi project described herein were the following items, followed in parentheses by interquartile and median dates: nitrogen oxides control (1979-1983-1990), new car batteries, fuel cells, steam, etc. (1980-1985-1992), and new fast and safe mass transit systems (1985-1992-2001) (28).

In another approach to predicting what the future will hold, the 67th Annual Meeting of the Air Pollution Control Association in June, 1974, presented a panel discussion of the topic "Long Term Goals for Environmental Control - What's Desirable and Possible in the Year 2000?" Four panel members presented their views on this subject; an economist, a politician, a lawyer and an engineer (18).

In view of the Delphi forecast which is a part of this paper, the thoughts of these four experts, speaking from their various points of view will be discussed briefly. The economist, Dr. Allen Kneese of the

University of New Mexico, projected the control of 14 pollutants to the year 2000 with the use of a sophisticated computer model which allowed for modest increases in control technology. According to this model, control of the pollutants can be achieved at an outlay of approximately three percent of the gross national product. When larger numbers of pollutants, trace materials, heavy metals and insecticides were included in the projections, Kneese predicted that all could be controlled at five to eight percent of the gross national product. Kneese did not advocate control by stopping economic growth, as some would. He did feel that there should be effluent charges for those industries discharging pollutants to the environment, with tax credits for those firms which reduce pollutant discharge. Finally, Kneese called attention to the great increases in world population which he felt will not slow down for decades, if ever, and will have a direct effect on the United States. He predicted that the threat of starvation will make some countries more willing to take risks in the use of hard pesticides and nuclear energy.

The Honorable Victor C. Goldbloom, Minister of Municipal Affairs of the Environment of Quebec, Canada, spoke from the politician's point of view. Goldbloom felt that the best progress in reducing air pollution was to be realized from the cooperation of government, industry and the public. Since government operates with the consensus of those it serves, cooperation between the three areas is essential. He spoke of the fact that "a government is foresight," and that "government has to choose" and that "government is a manager." Because of these factors, government cannot force its will on one particular sector of the economy (18).

Next, the Honorable Raymond J. Sherwin, Judge of the Superior Court of Fairfield, California, spoke from the legal viewpoint. Sherwin pinpointed

the overwhelming majority of pollutants as being derived from the combustion of fossil fuels for energy production. If petroleum and coal are non-renewable resources, then perhaps they should not be used for energy production, but reserved for such things as petrochemicals, pharmaceuticals and others. From what source then, would energy demands be satisfied? The most immediate answer would probably be nuclear energy; but having named this possibility, Sherwin went on to give a thumbnail history and state of the art of nuclear power plants. This was quite a sobering, and even frightening, sketch showing some of the serious problems and potentially disastrous effects from this energy source. Sherwin's proposals to eliminate these energy sources included emphasizing economy and efficiency in the utilization of fuel resources for all types of building and manufacturing operations and an all-out redirection of research efforts to concentrate on such potential energy sources at fusion, solar, geothermal, wind, magnetohydrodynamic and others. Finally, Sherwin cautioned against the optimistic predictions of the AEC and certain private industries, who have special interests to promote and seem to be present on most government advisory boards and study commissions. In his opinion these special interest groups need to be balanced by a wider spectrum of scientific and engineering thinking to obtain the most satisfactory solutions to energy and environmental problems.

The last speaker on the panel, representing the engineering and technological viewpoint, was Dr. Max S. Peters, Dean of the College of Engineering and Applied Science, University of Colorado. Peters took the audience to the year 2000, and looked back to see the various crises which had arisen and how they had been solved. The energy and food

crises, he said, had been solved by teamwork between engineers and scientists. He felt that engineers, because of their pragmatic scientific and technical training, can make a special contribution to help solve the environmental and other problems facing the United States and the world. Peters challenged his audience to get involved in community service projects, and where possible, politics as well (18).

CHAPTER 3

STUDY RESULTS

Technician Questionnaire

Of the total of 426 questionnaires sent out to government control agencies and private industrial or consulting firms, 246 usable replies were received. A follow-up letter was sent to those subjects from whom no response was received initially, copy of which is presented in Appendix E. This follow-up request resulted in six more responses from government agencies and two additional instruments from the private sector.

A comparison of rates of questionnaire return revealed that government control agencies returned 169 instruments of the 208 sent out for a return rate of 81.3%, while private industry and consulting firms returned 77 of 218 forms for a rate of 35.3%*. The combined return for both areas was 57.7%. These figures are summarized in Table 1. Examining this table, it appears that the follow-up letter resulted in little further action. The agency or firm made a decision whether or not to complete and return the form, and if the decision was negative, further requests for cooperation had little effect.

The weighted average score for each questionnaire item was calculated individually for both groups. The arithmetic average was calculated

*Nine usable responses were received from the 21 consulting firms contacted, a rate of 42.8%. By comparison, 68 industrial companies returned usable instruments for a rate of 34.5%.

TABLE 1

GOVERNMENT AGENCY AND PRIVATE INDUSTRY RESPONSES TO TECHNICIAN QUESTIONNAIRE

Organization	Number Mailed Out	Number Usable Replies Received: First Mailing	Second Mailing	Total	% Response
Government Control Agencies	208	163	6	169	81.3
Private Firms	218	75	2	77	35.3
Total	426	238	8	246	57.7

TABLE 2

INDIVIDUAL TECHNICIAN QUESTIONNAIRE ITEM WEIGHTS FROM GOVERNMENT AND INDUSTRY RESPONDENTS

Section	Item	Government	Industry	Average
A (Ambient Sampling)	1	4.500	1.973	3.237
	2	4.212	1.563	2.886
	3	3.700	1.739	2.720
	4	3.206	2.535	2.871
	5	3.048	3.197	3.123
	6	3.000	3.171	3.086
	7	3.509	2.111	2.810
	8	2.503	2.769	2.636
	9	3.905	2.028	2.967
	10	2.541	2.543	2.542
	11	4.855	1.732	3.294
	12	3.795	2.484	3.140
	13	2.063	2.936	2.500
	14	1.929	2.782	2.356
	15	2.111	2.854	2.483
	16	1.571	3.357	2.464
	17	1.495	3.500	2.498
	18	1.516	3.760	2.638
	19	1.557	3.750	2.654
	20	1.900	3.545	2.723
	21	2.847	2.366	2.607
	22	3.175	2.396	2.786
	23	3.053	2.631	2.842

TABLE 2 - continued

Section	Item	Government	Industry	Average
A	24	2.802	2.544	2.673
	25	2.190	2.926	2.558
	26	2.581	2.552	2.567
B	1	4.503	1.829	3.166
(Source	2	4.414	1.771	3.093
Sampling)	3	3.944	2.055	3.000
	4	4.509	1.750	3.130
	5	4.728	1.611	3.170
	6	4.469	1.639	3.054
	7	4.543	1.657	3.100
	8	3.586	2.257	2.922
	9	4.582	1.667	3.125
	10	4.006	2.118	3.062
	11	2.622	3.167	2.895
	12	4.000	3.000	3.500
	13	4.610	2.746	3.678
C	1	2.912	2.500	2.706
(Lab Analyses	2	3.347	2.303	2.825
& Equip.)	3	4.012	1.943	2.978
	4	2.591	3.441	3.016
	5	4.442	1.521	2.982
	6	2.947	2.304	2.626
	7	3.166	2.424	2.795
	8	3.137	2.688	2.913
	9	3.219	2.733	2.976
	10	2.972	3.000	2.986
	11	2.602	2.902	2.752
	12	4.062	2.344	3.203
	13	2.947	2.771	2.859
	14	3.000	2.446	2.723
	15	4.205	2.968	3.587
	16	4.121	2.467	3.294
	17	3.733	2.733	3.233
	18	4.006	2.300	3.153
	19	2.309	3.264	2.787
	20	2.409	3.151	2.780
	21	3.671	2.600	3.136
	22	3.894	2.365	3.130
	23	2.400	2.967	2.684
	24	2.743	2.831	2.787
	25	2.893	2.903	2.898
	26	3.287	2.864	3.076
D	1	3.094	2.273	2.684
(Meteorology)	2	4.207	2.296	3.252
	3	3.329	2.042	2.686
	4	3.658	2.859	3.259

TABLE 2 - continued

Section	Item	Government	Industry	Average
D	5	3.795	2.371	3.083
	6	3.468	3.194	3.331
	7	2.722	2.768	2.745
	8	2.870	2.941	2.906
	9	3.218	3.060	3.139
	10	3.717	2.667	3.192
	11	3.913	2.352	3.133
E (Cont.Meth. & Emiss. Surveys)	1	3.873	2.371	3.122
	2	4.049	2.333	3.191
	3	4.079	2.417	3.248
	4	4.055	2.352	3.204
	5	3.944	2.371	3.158
	6	3.666	2.750	3.208
	7	3.596	2.778	3.187
	8	3.858	2.700	3.279
	9	3.528	2.864	3.196
	10	4.163	2.297	3.230
	11	2.856	3.100	2.978
	12	3.591	2.642	3.117
F (Gen.A.P. Info.)	1	4.521	2.289	3.405
	2	4.461	2.013	3.237
	3	2.964	3.289	3.127
	4	3.886	2.662	3.274
	5	3.659	2.714	3.187
	6	3.599	2.636	3.118
	7	4.246	2.368	3.307
	8	3.731	2.789	3.260
	9	4.222	2.467	3.345
	10	4.114	2.158	3.136
	11	4.389	1.907	3.148
	12	3.366	2.200	2.783
	13	3.795	2.526	3.161
	14	3.431	2.680	3.056
	15	3.503	2.760	3.132
	16	3.573	2.808	3.191

for the two groups together (a "horizontal mix"). These data are presented, section by section, in Table 2. This table provides a comparison of the importance attached to the individual questionnaire items by government vs. private firms. From this table, comparisons can be made between individual items in the same or different sections by the same respondent group, or comparisons between respondent groups can be made. The arithmetic average for each item was calculated between the two respondent groups in this table. This was done because the larger number of respondents in the government group would have shifted the average far toward the government sector. From a practical standpoint, what was desired was an average value representing the midpoint between the judgment of government agencies on one hand and private firms on the other.

It should be kept in mind when studying the results presented in Table 2 through Table 6 that the decimals were not significant and included only for purposes of comparison.

The overall weighted section average was calculated separately for government and industry responses. The overall combined weighted average for each respondent group was then calculated. These data are presented in Table 3. A study of this table reveals that the overall weighted average by section was higher for government agencies for each of the six topic sections. This means that governmental respondents consistently placed higher importance on certain individual items than did private firms. Reasons for this were not obvious. The one overall inference which was drawn was that private firms did not think that technician training programs in this area were as important as governmental control agencies believed they were. Comparison of overall ratings section by section further showed that the two groups of respond-

TABLE 3

OVERALL WEIGHTED AVERAGE RATINGS
BY TECHNICIAN QUESTIONNAIRE SECTIONS

Section	Subject	Weighted Average Government	Weighted Average Industry	Overall
A	Ambient Sampling	2.894	2.622	2.814
B	Source Sampling	4.222	2.048	3.567
C	Lab Analyses & Equip.	3.293	2.624	3.097
D	Meteorology	3.464	2.612	3.206
E	Cont. Meth. & Emiss. Surveys	3.778	2.564	3.422
F	Gen A.P. Information	3.842	2.517	3.428
	Overall Average	3.485	2.521	

TABLE 4

HIGH, LOW, AND MEDIAN TECHNICIAN
QUESTIONNAIRE SECTION VALUES

Section	Number Items	Government High	Government Low	Government Median	Industry High	Industry Low	Industry Median
A	26	4.855	1.495	2.825	3.760	1.563	2.592
B	13	4.728	2.622	4.469	3.167	1.611	1.829
C	26	4.442	2.309	3.069	3.441	1.521	2.711
D	11	4.207	2.722	3.468	3.194	2.042	2.667
E	12	4.163	2.856	3.866	3.100	2.297	2.530
F	16	4.521	2.963	3.763	3.289	1.907	2.581

ents did not agree on which sections were the most important. Thus, the single most important category to government agencies was Source Sampling, followed by General Air Pollution Information, which was closely followed by Control Methods and Emission Surveys. Private firms put the highest importance on three categories whose overall rankings were very close to each other; Lab Analyses and Equipment, Ambient Sampling, and Meteorology. The lowest importance was assigned to Source Sampling, almost the reverse of the governmental rankings.

The weighted average for each section was calculated for the two respondent groups. It can be seen that the order of rankings from highest importance to lowest, section by section, was the same for the overall average of both groups as for the government respondents alone.

Extracted from Table 2 were the high, low and median item values for each section which are presented in Table 4. Scanning this table, one can see that the high values for each section were at least one point higher for government responses than for corresponding industry responses. While there was not quite this much difference between the low values, government responses were still consistently higher than private industry responses. This same disparity was also evident in the median values.

Differences within groups were not as pronounced: the range of highs for government responses was 4.1 to 4.8, and for industry, 3.1 to 3.7 The low values for government ranged from approximately 1.5 to 2.9, while for industry, the low range was 1.5 to approximately 2.3. The range of median values for government agencies was 2.8 to approximately 4.5, and for the private sector, 1.8 to 2.7.

In general, ranges between high and low values were narrower for industry responses than for government agencies, and government agencies

tended to assign higher importance to topic items than industry.

After calculating the weighted average score for each individual questionnaire item, the items were ranked in descending order of importance by section. Comparisons of the rankings and scores section by section between the two major respondent groups revealed widely varying degrees of importance assigned to individual items. Table 5 shows the government agency responses for individual items ranked from highest importance to lowest, section by section, side by side with the same data representing private industry and consulting firms.

In topic Section A, concerned with Ambient Sampling, item 11 received the highest score from Government Agencies (4.855) while item 18 received the highest score (3.760) from private industrial firms. The lowest ranking item in this section was number 17, which received a score of 1.495 from government agencies, while item number 2 was lowest for the private sector, and received a score of 1.563. Similarly, individual item rankings can be compared between government agencies and private firms for each section. Again, it should be stressed that the decimals included for each item are for the purposes of ranking and comparison only and are not intended to imply significant differences between adjacent items. For example, there is probably little difference between items 18 and 19 in Section A as rated by private firms (3.760 vs. 3.750). The reason for this is inherent in the nature of the scale used, which was an ordinal, and not an interval scale.

From the data in Table 2, Tables 6 and 7 were prepared. These tables show individual questionnaire items ranked in order of descending importance for all 104 items regardless of the original six alphabetical

TABLE 5

RANK ORDER OF TECHNICAL QUESTIONNAIRE ITEMS BY SECTION

Section	Rank	Government Item	Government Score	Industry Item	Industry Score
A (Ambient Sampling)	1	11	4.855	18	3.760
	2	1	4.500	19	3.750
	3	2	4.212	20	3.545
	4	9	3.905	17	3.500
	5	12	3.795	16	3.357
	6	3	3.700	5	3.197
	7	7	3.509	6	3.171
	8	4	3.206	13	2.936
	9	22	3.175	25	2.926
	10	23	3.053	15	2.854
	11	5	3.048	14	2.782
	12	6	3.000	8	2.769
	13	21	2.847	23	2.631
	14	24	2.802	26	2.552
	15	26	2.581	24	2.544
	16	10	2.541	10	2.543
	17	8	2.503	4	2.535
	18	25	2.190	12	2.484
	19	15	2.111	22	2.396
	20	13	2.063	21	2.366
	21	14	1.929	7	2.111
	22	20	1.900	9	2.028
	23	16	1.571	1	1.973
	24	19	1.557	3	1.739
	25	18	1.516	11	1.732
	26	17	1.495	2	1.563
B (Source Sampling)	1	5	4.728	11	3.167
	2	13	4.610	12	3.000
	3	9	4.582	13	2.746
	4	7	4.543	8	2.257
	5	4	4.509	10	2.118
	6	1	4.503	3	2.055
	7	6	4.469	1	1.829
	8	2	4.414	2	1.771
	9	10	4.006	4	1.750
	10	12	4.000	9	1.667
	11	3	3.944	7	1.657
	12	8	3.586	6	1.639
	13	11	2.622	5	1.611
C (Lab.Analyses & Eqpt.)	1	5	4.442	4	3.441
	2	15	4.205	19	3.264
	3	16	4.121	20	3.151
	4	12	4.062	10	3.000
	5	3	4.012	15	2.968

TABLE 5 - continued

Section	Rank	Government Item	Score	Industry Item	Score
C (Lab Analyses & Eqpt.)	6	18	4.006	23	2.967
	7	22	3.894	25	2.903
	8	17	3.733	11	2.903
	9	21	3.671	26	2.864
	10	2	3.347	24	2.831
	11	26	3.287	13	2.771
	12	9	3.219	9	2.733
	13	7	3.166	17	2.733
	14	8	3.137	8	2.688
	15	14	3.000	21	2.600
	16	10	2.972	1	2.500
	17	13	2.947	16	2.467
	18	6	2.947	14	2.446
	19	1	2.912	7	2.424
	20	25	2.893	22	2.365
	21	24	2.743	12	2.344
	22	11	2.602	6	2.304
	23	4	2.591	2	2.303
	24	20	2.409	18	2.300
	25	23	2.400	3	1.943
	26	19	2.309	5	1.521
D (Meteorology)	1	2	4.207	6	3.194
	2	11	3.913	9	3.060
	3	5	3.795	8	2.941
	4	10	3.717	4	2.859
	5	4	3.658	7	2.768
	6	6	3.468	10	2.667
	7	3	3.329	5	2.371
	8	9	3.218	11	2.352
	9	1	3.094	2	2.296
	10	8	2.870	1	2.273
	11	7	2.722	3	2.042
E (Control Methods & Emiss.Surveys)	1	10	4.163	11	3.100
	2	3	4.079	9	2.864
	3	4	4.055	7	2.778
	4	2	4.049	6	2.750
	5	5	3.944	8	2.700
	6	1	3.873	12	2.642
	7	8	3.858	3	2.417
	8	6	3.666	1	2.371
	9	7	3.596	5	2.371
	10	12	3.591	4	2.352
	11	9	3.528	2	2.333
	12	11	2.856	10	2.297
F(Gen.A.P.Info.)	1	1	4.521	3	3.289

TABLE 5 - continued

Section	Rank	Government Item	Government Score	Industry Item	Industry Score
F (Gen.A.P.Info.)	2	2	4.461	16	2.808
	3	11	4.389	8	2.789
	4	7	4.246	15	2.760
	5	9	4.222	5	2.714
	6	10	4.114	14	2.680
	7	4	3.886	4	2.662
	8	13	3.795	6	2.636
	9	8	3.731	13	2.526
	10	5	3.659	9	2.467
	11	6	3.599	7	2.368
	12	16	3.573	1	2.289
	13	15	3.503	12	2.200
	14	14	3.431	10	2.158
	15	12	3.366	2	2.013
	16	3	2.964	11	1.907

TABLE 6

COMBINED AVERAGE RANKING OF
TECHNICIAN QUESTIONNAIRE ITEMS

Rank	Overall Average	Item	Rank	Overall Average	Item
1	3.678	B-13	46	3.122	E-1
2	3.587	C-15	47	3.118	F-6
3	3.500	B-12	48	3.117	E-12
4	3.405	F-1	49	3.100	B-7
5	3.345	F-9	50	3.093	B-2
6	3.331	D-6	51	3.086	A-6
7	3.307	F-7	52	3.083	D-5
8	3.294	A-11	53	3.076	C-26
9	3.294	C-16	54	3.062	B-10
10	3.279	E-8	55	3.056	F-14
11	3.274	F-4	56	3.054	B-6
12	3.260	F-8	57	3.016	C-4
13	3.259	D-4	58	3.000	B-3
14	3.252	D-2	59	2.986	C-10
15	3.248	E-3	60	2.982	C-5
16	3.237	A-1	61	2.978	C-3
17	3.237	F-2	62	2.978	E-11
18	3.233	C-17	63	2.976	C-9
19	3.230	E-10	64	2.967	A-9
20	3.208	E-6	65	2.922	B-8
21	3.204	E-4	66	2.913	C-8
22	3.203	C-12	67	2.906	D-8
23	3.196	E-9	68	2.898	C-25
24	3.192	D-10	69	2.895	B-11
25	3.191	E-2	70	2.886	A-2
26	3.191	F-16	71	2.871	A-4
27	3.187	E-7	72	2.859	C-13
28	3.187	F-5	73	2.842	A-23
29	3.170	B-5	74	2.825	C-2
30	3.166	B-1	75	2.810	A-7
31	3.161	F-13	76	2.795	C-7
32	3.158	E-5	77	2.787	C-19
33	3.153	C-18	78	2.787	C-24
34	3.148	F-11	79	2.786	A-22
35	3.140	A-12	80	2.783	F-12
36	3.139	D-9	81	2.780	C-20
37	3.136	C-21	82	2.752	C-11
38	3.136	F-10	83	2.745	D-7
39	3.133	D-11	84	2.723	A-20
40	3.132	F-15	85	2.723	C-14
41	3.130	B-4	86	2.720	A-3
42	3.130	C-22	87	2.706	C-1
43	3.127	F-3	88	2.686	D-3
44	3.125	B-9	89	2.684	C-23
45	3.123	A-5	90	2.684	D-1

TABLE 6 - continued

Rank	Overall Average	Item	Rank	Overall Average	Item
91	2.673	A-24	98	2.558	A-25
92	2.654	A-19	99	2.542	A-10
93	2.638	A-18	100	2.500	A-13
94	2.636	A-8	101	2.498	A-17
95	2.626	C-6	102	2.483	A-15
96	2.607	A-21	103	2.464	A-16
97	2.567	A-26	104	2.356	A-14

TABLE 7

OVERALL RANK ORDER OF INSTRUCTIONAL ITEMS DERIVED FROM TECHNICIAN QUESTIONNAIRE

Rank	Item	Topic
1	B-13	Certification as smoke reader
2	C-15	Carbon monoxide-NDIR method
3	B-12	Ringelmann chart
4	F-1	Definition of air pollution
5	F-9	Major pollutants and levels of emission
6	D-6	Lapse rates
7	F-7	General effects on animals and human health
8	A-11	Suspended particulates - high vol method
9	C-16	Oxidants-chemiluminescent method
10	E-8	Incineration, flame combustion
11	F-4	General effects on atmosphere
12	F-8	Major national sources of air pollutants
13	D-4	Wind turbulence and mixing heights
14	D-2	Wind speed and direction indicator
15	E-3	Principles of filtration collectors
16	A-1	Reasons for ambient sampling
17	F-2	Classifications of air pollutants
18	C-17	Oxidants-neutral buffered KI method
19	E-10	Source emission inventories
20	E-6	Gas absorption equipment
21	E-4	Principles of wet collectors
22	C-12	SO_2-pararosaniline (Photometric) method
23	E-9	Incineration, catalytic combustion
24	D-10	Wind roses
25	E-2	Principles of mechanical collectors
26	F-16	Atmospheric reactions of air pollutants
27	E-7	Gas adsorption equipment
28	F-5	General effects on vegetation
29	B-5	Gas velocity measurements
30	B-1	Objectives of testing
31	F-13	Characteristics of a control program
32	E-5	Principles of electrostatic precipitators
33	C-18	Hydrocarbons-flame ionization method
34	F-11	Air quality standards
35	A-12	Soiling index-paper tape sampler
36	D-9	Movement of air masses and fronts
37	C-21	NO_2 (Griess-Saltzman Reaction)
38	F-10	Air quality criteria
39	D-11	Diffusion from an air pollution source
40	F-15	Typical legislation-state government
41	B-4	Measurement of pressure and temperature
42	C-22	NO_x
43	F-3	Historical aspects of air pollution
44	B-9	Sampling train components
45	A-5	Principles of absorption
46	E-1	Criteria for equipment selection

TABLE 7 - continued

Rank	Item	Topic
47	F-6	General effects on materials
48	E-12	Control by process or equipment change
49	B-7	Isokinetic sampling conditions
50	B-2	Sampling site criteria
51	A-6	Principles of adsorption
52	D-5	Anemometers
53	C-26	Lead
54	B-10	Orsat analyzer
55	F-14	Air pollution legislation-federal government
56	B-6	Gas flow calculations
57	C-4	Use of digital computer
58	B-3	Gas laws
59	C-10	Ultraviolet absorption
60	C-5	Calculation, analysis and presentation of data
61	C-3	Use of desk calculators
62	E-11	Control by zoning
63	C-9	Infrared absorption
64	A-9	Principles of impinger operation
65	B-8	Apparent molecular weight
66	C-8	Atomic absorption spectrophotometer
67	D-8	Precipitation
68	C-25	Chlorides and chlorine compounds
69	B-11	Smokescope
70	A-2	Sampling site selection criteria
71	A-4	Physical properties of aerosols and particulates
72	C-13	Sulfuric acid mist
73	A-23	Membrane filter
74	C-2	Particle size distribution
75	A-7	Principles of grab sampling
76	C-7	Gas chromatograph
77	C-19	Organic acids
78	C-24	Fluorides
79	A-22	Anderson samplers
80	F-12	Threshold limit values
81	C-20	Aldehydes
82	C-11	Emission spectroscopy
83	D-7	Evaporation and condensation
84	A-20	Rotorod sampler
85	C-14	Hydrogen sulfide
86	A-3	Determination of sample size required
87	C-1	Particle counter
88	D-3	Moisture content and dew point
89	C-23	Ammonia and ammonium compounds
90	D-1	Psychrometry
91	A-24	Electrostatic precipitator
92	A-19	Rubber cracking strips
93	A-18	Fabric panels
94	A-8	Principles of freezeout sampling
95	C-6	Microscopic analyses

TABLE 7 - continued

Rank	Item	Topic
96	A-21	Cascade impactors
97	A-26	MSA universal tester
98	A-25	Thermal precipitator
99	A-10	Dustfall
100	A-13	Sticky tape samplers
101	A-17	Silver coated plates
102	A-15	Sulfation rate-sulfation plate method
103	A-16	Corrosion plates
104	A-14	Sulfation rate-lead candle method

sections (a "vertical mix"). As can be seen from Table 6, there was a gradual decrease in the average values from a high of 3.678 for item B-13 to a low of 2.356 for item A-14. Differences between adjacent items were generally small and were not statistically significant. In using these tables for purposes of determining curriculum content of an air pollution technician training program, an arbitrary choice must be made as to those items to be included and those to be omitted. Obviously this decision will be made based on the needs and dictates of the individual program. Assuming the necessary subject expertise is available within the faculty and that laboratory and equipment resources are adequate, then the most important remaining parameter is time. It is not likely that sufficient time exists in the normal two-year program curriculum to cover all 104 topic items in depth. Therefore, those items receiving the highest average ratings should definitely be included, while those receiving the lowest ratings should be either omitted or given less time.

In this discussion, it has been assumed that the training program has been designed to produce control technicians capable of working either in private industry or for government control agencies. In the event that a program was intended to prepare technicians exclusively for government agency service, then perhaps Table 5 should be used for the specific ratings as supplied by government agencies. The same observation would hold for industrial control technician programs. Since, as of the present writing, there were no known training programs designed for either sector exclusively, Table 7 would logically be the proper table to use.

In examining Table 6, several observations can be made. First, most of the items from Section E, Control Methods and Emission Surveys

were contained in the upper half of the rankings. The same observation can be made with regard to Section F, General Air Pollution Information. On the other hand, items from Section A, Ambient Sampling, seem to be concentrated near the bottom of the rankings.

In Table 7, the individual topic items corresponding to the rankings of Table 6 are presented. It was noted that the single item having the highest average weight, and presumably the highest importance to both groups, was item B-13, Certification as a Smoke Reader, while the item receiving the lowest overall rating from both groups was A-14, Sulfation Rate - Lead Candle Method.

In Table 8, the questionnaire item rankings were broken at the median to show those items in the top half and those which were ranked in the bottom half. Thus, nearly 92% of the items from Section A, Ambient Sampling, (11 of 12 items) were contained in the top half. Approximately 88% of the items from Section F, General Air Pollution Information, were included in the top half (14 of 16 items). Similarly, only 19% of the items from Section A were in the upper half, with the remaining 81% in the bottom half.

Table 9 further refined these data into quartile distributions. It can be seen that the section ranking sequence in Table 8 was the same for Table 9. The relative importance of the various sections was illustrated in this table. Of the 12 items in Section E, Control Methods and Emission Surveys, seven, or 58%, were ranked in the upper quartile of all items. For the 11 items in Section D, Meteorology, over one-third appeared in the upper quartile. The Source Sampling category, Section B, showed 11 of 13 items appearing in the upper middle and lower middle quartiles with no items assigned to the lowest quartile. Although

TABLE 8

RANKING OF TECHNICIAN QUESTIONNAIRE SECTIONS BY HALVES

Section	Topic	Halves, % Items Contained in Each: Upper	Lower	Total No. Items
E	Control Method & Emission Surveys	91.7 (11)	8.3 (1)	(12)
F	General Air Pollution Information	87.5 (14)	12.5 (2)	(16)
D	Meteorology	63.6 (7)	36.4 (4)	(11)
B	Source Sampling	61.5 (8)	38.5 (5)	(13)
C	Laboratory Analyses and Equipment	26.9 (7)	73.1 (19)	(26)
A	Ambient Sampling	19.2 (5)	80.8 (21)	(26)

Note: Numerals in parentheses refer to the number of topic items in that section.

TABLE 9

RANKING OF TECHNICIAN QUESTIONNAIRE SECTIONS BY QUARTILES

Section	Quartiles, % Items Contained in Each: Upper	Upper Middle	Lower Middle	Lower	Total Number Items
E	58.3 (7)	33.3 (4)	8.3 (1)	0 (0)	(12)
F	43.8 (7)	43.8 (7)	6.3 (1)	6.3 (1)	(16)
D	36.4 (4)	27.3 (3)	9.1 (1)	27.3 (3)	(11)
B	15.4 (2)	46.2 (6)	38.5(5)	0 (0)	(13)
C	15.4 (4)	11.5 (3)	50.0(13)	23.1 (6)	(26)
A	7.7 (2)	11.5 (3)	19.2(5)	61.5 (16)	(26)

Note: Numerals in parentheses refer to the number of topic items in that section.

Sections C and A each contained 26 items, only four from Section C, Lab Analyses and Equipment, and two from Section A appeared in the upper quartile. Approximately 62% of the items in Section A (16 of a total of 26) appeared in the lowest quartile. The numbers in parentheses refer to the number of items contained in that section.

Perusual of the rankings of questionnaire items contained in the various tables indicated little apparent correlation between government and industry respondents as to which items were the most important. In some cases there was a suggestion of negative correlation: those items ranked high by government agencies received low ratings from industry, and conversely, industry seemed to place high values on items rated lower by government control agencies.

In an effort to determine whether this was the case, Spearman rank order correlation coefficients were calculated for each section using the relationship $r_s = 1 - \frac{6(\Sigma d^2)}{n^3 - n}$

where r_s = Spearman rank order coefficient

Σd^2 = sum of rank order differences squared

n = number of items ranked.

The Spearman rank order correlation coefficient is used in non-parametric statistical applications and is appropriate for data derived from ordinal scales such as the one used in this project. To illustrate briefly the use of this method, suppose four items a, b, c, d were to be ranked from highest to lowest importance by two subjects independently. If both subjects ranked the items in the sequence a, b, c, d, calculation of the Spearman rank order coefficient would result in $r_s = 1.00$, a perfect positive correlation. However, if one subject ranked the items a,

b, c, d, and the second subject ranked the items d, c, b, a, calculation of the coefficient from these data would produce $r_s = -1.00$, a perfect negative correlation, meaning that the two subjects ranked the items exactly the opposite of each other. Thus, Spearman coefficients range from -1.00 to +1.00; the closer the positive number approaches 1.00, the stronger the positive correlation, and the closer negative coefficients approach -1.00, the stronger the negative correlation. A coefficient near zero indicates a low order of correlation. Finally, the Spearman coefficient can be checked in a statistical table to determine its significance at various levels (25, 35).

In Table 10, Spearman rank order correlation coefficients were calculated for two sets of ranked items. First, the Spearman coefficients were calculated for the regular ranking of questionnaire items according to the importance assigned to them by government agencies versus private industrial firms. In all six sections, negative correlations were obtained. It will be recalled that respondents were asked to rate the importance of individual questionnaire items as to whether they were of high importance, moderate importance, or low importance. Values assigned to each of these ratings were, respectively, five, three and one. A fourth rating category was marked N/A and respondents were asked to check this column for those items which were not applicable to their needs or testing program. Items which were placed in the N/A category were not weighted and did not enter into the item rankings. In view of the results noted above, however, it was suspected that the N/A ratings had somehow skewed the data to produce the apparent negative correlations indicated. To test this hypothesis, a value of zero was assigned to the N/A items and the weighted values for each item were calculated as before.

TABLE 10

SPEARMAN RANK ORDER
CORRELATION OF GOVERNMENT AND INDUSTRY DATA
DERIVED FROM TECHNICIAN QUESTIONNAIRE

		Spearman Rank Order Coefficient r_s	
Section	Topic	Excluding N/A Data	Including N/A Data
A	Ambient Sampling	-0.884**	-0.451*
B	Source Sampling	-0.643*	-0.532*
C	Laboratory Analyses and Equipment	-0.658**	-0.679**
D	Meteorology	-0.291	-0.282
E	Control Methods and Emission Surveys	-0.881**	-0.446
F	General Air Pollution Information	-0.679**	-0.621**

* Significant at the .05 level
** Significant at the .01 level

After ranking the results for each section, Spearman coefficients were calculated. These figures appear beside the coefficients calculated first (excluding the N/A data).

Examining Table 10, several facts emerged. First, it was noted that all Spearman coefficients had a negative sign, indicating some degree of negative correlation between government agencies and private industrial firms. Next, of those rankings excluding N/A data, the coefficients obtained for five of six sections were significant at the .05 level. Further, of those five sections, four were also significant at the .01 level. When the N/A data were included in the rankings, the negative correlations were diminished in several cases so that four of six coefficients were significant at the .05 level and two were significant at the .01 level. However, it will be noted that none of the sections were converted to positive coefficients by inclusion of the N/A data.

On the basis of these data, there appeared to be little question that government agencies recognized priorities in air pollution control activities different from those perceived by private firms. As observed before, the reasons why this should be so were not readily apparent.

Added to the bottom of the last page of the survey document was the item Other important concepts or procedures. In the cover letter accompanying the checklist, a request was made to include under this item any other test procedures, knowledges or capabilities the respondent felt should be possessed by a competent technician. Only a small number of respondents entered comments under this item. There appeared to be a high degree of similarity between the observations submitted by industry and government respondents. Therefore, the nature of all the added

comments for both groups has been summarized below:

1. Training in equipment maintenance and repair (trouble shooting continuous monitors and recording instrumentation)
2. Legal aspects and court proceedings
3. Statistics
4. Accounting procedures and business practices
5. Technical report writing
6. Public relations
7. Fundamentals of electricity/electronics and mechanics
8. Logic and use of computers in calculations
9. Economics
10. Micrometeorology and effects of multiple stack emissions
11. Sources of technical data such as OSHA standards and EPA standard test methods
12. Permit registration procedures
13. Fuels and fuel sampling
14. Complaint investigation and field enforcement
15. Inspection techniques
16. Specific analytical or testing procedures:
    a. sulfur gases
    b. nitrogen oxides
    c. carbon monoxide
    d. chemiluminescent, optical and chemical methods
    e. explosive properties of gases and dusts
    f. oil mists
    g. EPA sampling train
    h. flame photometry, gas chromatography

Specialized training in more than a dozen different areas was recommended as being of importance to air pollution control technicians. Respondents from government agencies tended to place more importance on public relations, legal aspects, complaint investigation and permit-

registration procedures, while private sector respondents emphasized business practices and specific testing and analytical procedures. Both sectors agreed on the importance of such topics as technical report writing, equipment maintenance and repair, basic mechanics and electronics, and computer calculation procedures.

Two final observations on the comments should be made. First, the reader will note by comparing the list of suggested additions to the curriculum with the items contained in the questionnaire, that several items contained in the suggestions were listed in the questionnaire. Whether the respondent was not aware of, or forgot the contents of the questionnaire when he wrote his extra comments, or whether he simply felt that they should be restated to gain added emphasis was not known. Second, a side effect was noted in the comments of several respondents. These comments were generally opinions and judgments relating to the Air Pollution Control Technology curriculum at Santa Fe Community College. The comments tended to be critical of the length of the program and the great number of topics covered. Referring to the questionnaire and instructions presented in Appendix A, it will be noted that nowhere is the actual curriculum at Santa Fe indicated or referred to. The instrument simply contained an extensive list of topics dealing with various phases of air pollution and asked the respondent to indicate how important <u>he</u> felt each would be to a two-year technician training program.

The notion that the list somehow represented Santa Fe's curriculum, then, was inferred by these respondents and indicates how varied a response may be obtained from a mail-out type instrument which depends on the respondent clearly understanding what is requested of him.

Delphi Procedure and Results

It was originally intended that the expert panel for the Delphi forecast be comprised of members of the advisory committee who assisted in the preparation of the publication Air Pollution Technology: A Suggested Two-Year Post High School Curriculum. On further reflection, however, two factors were recognized which changed the original plan. First, it was feared that the small number of advisory committee members (12 in all) might not present a broad enough base to reflect accurately the air pollution control community. The second factor, and a corollary to the first, was the realization that some of the advisory committee members might be unwilling or unable to take part in the project, thus further reducing the number of participants. Consequently, it was decided to enlarge the panel to a total of 40 members. Criteria for selecting the remaining 28 potential participants have been discussed previously.

After a period of time elapsed following the first mailing (approximately seven weeks), a follow-up letter was sent to those individuals who had not responded. The follow-up letter was responsible for producing four additional responses, for a total of 11 usable replies on the first round. The follow-up letter is included in Appendix E.

From the responses received, a list of 25 items emerged. The tabulated list of items showing earliest, latest and median dates for each event was sent to the panel for round two. Although four individuals in the original mailing specifically declined to participate, the second round mailing went to 37 individuals, including those who did not respond to the first round.

The four individuals who wrote specifically to decline to partici-

pate in the projections provided an insight into some of the problems inherent in this type project. One individual pleaded a lack of time to formulate specific items and dates for their realization. This individual subsequently participated in both the second and third rounds of the forecast. The second individual confessed to a complete inability to look into the future and asked to be excused on that account. The third individual expressed a distrust and lack of confidence in the Delphi process as a means of providing meaningful information. The fourth individual was the Director of a large government control agency. A member of his staff had served on the curriculum guide advisory committee referred to earlier. Since the staff member was participating in the Delphi forcast, the Director declined to be included.

After allowing a period of time for replies to the second round (approximately two months), a follow-up letter was sent, copy of which is included in Appendix E. The follow-up letter in this case produced three additional replies.

Following the mailing of the second round follow-up letter, two individuals (who had not responded to any of the earlier correspondence or requests) wrote to decline the offer to participate. One individual felt that the first two sections; Air Quality Measuring/Monitoring and Air Quality Regulations/Control were entirely inappropriate since in his estimate, the necessary regulations, technology and equipment already existed to obtain satisfactory control of air pollutant emissions. He was further uncertain as to how anyone could predict when the items under the General Energy/Environment category might occur. The other individual simply returned the second round follow-up letter with the words "please delete" written near his own name and address.

On the second round, usable responses were received from 21 individuals. Dates obtained on the second round were tabulated chronologically and the same procedure used to obtain interquartile earliest, latest and median dates. On the second round, several panel members requested that additional items be added to the list for evaluation by the entire panel. As a result, on the third (and final) round, a fourth section was added to the end of the tabulation. This added section contained three items, bringing the total number to 28. Because fewer responses were obtained than hoped for, it was decided to add ten new individuals to the panel. Criteria for selecting these individuals were the same as those used originally. A copy of the letter sent to each individual will be found in Appendix E. Thus, the final round was sent to 44 individuals, again including some from whom no response had been received on either of the two previous rounds. A summary of the responses to the Delphi project is presented in Table 11. In examining this table, it was noted that the highest rate of response was obtained on the second round, with the first round producing the lowest rate. Further, had the 10 extra individuals not been added for the third round, the response rate for that round would have been 50% (no usable replies were received from any of the ten individuals who were added for Round Three).*

A total of 22 individuals participated in one or more rounds of the Delphi forecast. This is one more than the number who participated in

*Actually, indirect responses were received from three of the ten individuals added for the third round. The tabulations had been completed by subordinates or colleagues, however, and not by the persons to whom the requests had been sent. It was decided that the original criteria used to select prospective panel members precluded the use of these responses; hence, they were not entered into the final tabulations.

TABLE 11

RESPONSES TO DELPHI PROJECT

Round	Number Requests Sent Out	Number Usable Replies Received	% Response
1	40	11	27.5
2	37	21	56.8
3	44	17	38.6

TABLE 12

DELPHI PANEL PARTICIPANTS

Category	Number of Individuals
Private Industry Engineer/Scientist	3
Private Consulting Engineer/Scientist	5
Government Control Agency Official	8
University Professor	5
Other	1
Total	22

Round Two (the round with the highest rate of participation) because one individual who participated in the first round did not participate in Rounds Two or Three. Personal data on the 22 participants provided an insight into the composition of the Delphi panel. Of the 22 individuals, three were engineers or scientists in private industry. Five individuals were, at the time for the forecast, private consulting engineers or scientists and eight were governmental control agency officials. Five were university professors and one was a technical journal executive. The data discussed here are summarized in Table 12. In considering these data, however, it should be kept in mind that there is a high degree of mobility across many of these categories. For example, several participants who were listed as private consultants or employed by private industry, have been in the past university professors. In addition, it should be recognized that many university professors also act as consultants to private firms as well as government control agencies.

Educational background of the panel participants was extensive. Six individuals had doctoral degrees and the remainder had baccalaureate and/or master's degrees.

Examining the list of participants in the project, personal acquaintance with the panel members evidently played an important role. Of the 12 members who served previously on the curriculum guide advisory committee, 10 participated in one or more rounds of the Delphi projections, a rate of slightly over 83%. By comparison, none of the 28 individuals added to the original group was personally known to the author, and of this latter group 12 participated in one or more rounds, a rate slightly less than 43%.

Finally, as noted before, of the group of 10 individuals added

for the last round (again, none of whom was personally known to the author), no usable responses were received. A list of the 22 Delphi participants is presented in Appendix F.

Table 13 presents a tabulation of the Delphi project results showing the earliest, latest and median realization dates for each event projected by the panel. It should again be stressed that the earliest and latest dates are the interquartiles and not the extreme earliest and latest dates estimated by individual panel members. These dates were used to arrive at the interquartile range, shown in the last column. Examination of this table revealed a wide variation in interquartile ranges from a low of two years to a high of 520 years.

Table 14 presents a comparison of interquartile ranges from the Delphi tabulation. In this table, Sections III and IV were combined. This was done for purposes of simplifying the table. It was felt that the three items in Section IV (Added Items) were most closely related to those in Section III (General Energy/Environment). Arbitrary divisions for interquartile ranges were selected: 10 years or less, 11-25 years, and greater than 25 years. All interquartile ranges were accordingly assigned to one of these categories. Thus, in Section I containing nine items and covering the topics related to Air Quality Measuring/Monitoring activities, two items had interquartile ranges of 10 years or less, five were in the 11-25-year range and two were greater than 25 years. Similarly, for Section II, four items had interquartile ranges of 10 years or less, five were in the 11-25 category and four were greater than 25 years. For the combined Sections III and IV, no items had interquartile ranges of 10 years or less, while two were in the 11-25-year category and four were greater than 25 years.

TABLE 13
DELPHI PROJECTION RESULTS

Item	Event	Realization of Event, year Earliest	Median	Latest	Inter-Quartile Range, Years
I	Air Quality Measuring/Monitoring				
1.	Automatic/remote measurement systems using techniques such as lidar, laser, spectroscopic, or fluorescent-luminescent methods	1977	1984	1990	13
2.	Continuous monitoring/mapping of air quality from satellites or high altitude aircraft	1978	1984	1990	12
3.	Development and use of reliable continuous particulate counting equipment capable of making size separations	1978	1989	2000	22
4.	Development and acceptance of reliable continuous monitoring equipment for the following pollutant sources-types				
	a. Continuous monitoring of stationary sources	1975	1978	1980	5
	b. Non-methane hydrocarbons	1978	1981	1983	5
	c. Odor	1978	1989	2000	22
	d. Heavy Metals	1975	1988	2000	25
	e. All-pollutant, single-instrument, computer-controlled analyzers	1990	2045	2100	110
	f. Organics	1980	2040	2100	120

TABLE 13 - continued

Item	Event	Realization of Event, year: Earliest	Median	Latest	Interquartile Range, Years
II	Air Quality Regulations/Control				
1.	Development of nation-wide air quality index*	1977	1989	2000	23
2.	Development and enactment of air quality standards				
	a. Ambient standards for sulfates	1978	1979	1980	2
	b. Particulates based on size	1978	1979	1980	2
3.	Pollution-free incineration of refuse for power generating capabilities	1975	1983	1990	15
4.	Control of NO_x emissions (by process change or control technology)	1978	2014	2050	72
5.	Development of high temperature (1000°F) baghouse fabric	1980	1985	1990	10
6.	Control of smoke to non-visible or nearly non-visible plumeconditions	1980	1985	1990	10
7.	Coal gasification/desulfurization	1979	2002	2025	46
8.	Development of a pollution-free power source for individual transportation (hydrogen fuel cells, solar, i.c., etc.)	1980	2015	2050	70
9.	Correlation of ambient levels with stack emissions so that air quality monitoring can be used to indicate allowable atmospheric loading	1985	1993	2000	15

TABLE 13 - continued

Item	Event	Realization of Event, year: Earliest	Median	Latest	Interquartile Range, Years
10.	Control/removal of SO_x emissions in				
	a. All stationary sources	1976	1988	2000	24
	b. Industry	1980	1988	1995	15
	c. Power plants**	1980	1995	2010	30
III	General Energy/Environment				
1.	Widespread use of "planned community" approach to urban planning, incorporating air quality aspects	1974	2000	2025	51
2.	Development and use of urban mass transit systems	1980	2240	2500	520
3.	Widespread use of hydrogen as fuel	1990	2020	2050	60
IV	Added Items				
1.	Use of pyrolysis for energy production from refuse	1980	1990	2000	20
2.	Use of wind generators for limited energy applications	1983	1992	2000	17
3.	Widespread electric power generation from solar energy	1985	2004	2023	38
*	Dates for this item, first two rounds, were:	1975	1988	2000	25
**	Dates for this item, first round only, were:	1980	2040	2100	120

TABLE 14

SUMMARY OF DELPHI INTERQUARTILE RANGES

Section	No. Items In Section	Interquartile Range, No. of Items: 10 years or less	11-25 years	greater than 25 years
I	9	2	5	2
II	13	4	5	4
III & IV	6	0	2	4
Totals	28	6	12	10

Examining again the tabulation of Delphi results in Table 13, it was noted that only two items, II-1 and II-10c changed between successive rounds. For item II-1, Development of nationwide air quality index, the earliest date changed from 1975 on the second round to 1977 on the third round. On item II-10c, Control/removal of SO_x emissions in power plants, the latest date changed from 2100 in the first round to 2010 in the second round. The dates for the other items remained unchanged throughout the three rounds of the project. However, it appeared that Delphi dates were at least potentially subject to quite radical changes between rounds,and in certain circumstances, these changes could have been triggered by as few as one or two individuals. In referring to the list of items forecast by the Delphi panel, item III-2, Development and use of urban mass transit systems, the earliest and latest dates from the first two rounds were, respectively, 1980 and 2500. On the final round, responses received from nine individuals were marked, for this item, "ok", "no change" or had no mark at all, which was interpreted as no change in that date for that respondent. However, the remaining eight replies all had earlier dates listed for the latest date for this item. These eight dates ranged from the year 2000 to 2100. Had one more reply been received listing a date of 2100 (or any date earlier), the latest date would have dropped from 2500 to 2300, a change of two centuries. Likewise, the median would have changed from 2240 to 2140, or one century earlier.

The reverse of this, stability from round to round, was exhibited by item III-3, Widespread use of hydrogen as fuel. On the final round, all 17 respondents agreed with the dates given on the previous round.

Median expected occurrence dates for all Delphi topics were put in chronological order. These data are presented in Table 15. Inspection of this table revealed that of the three major topic areas (it was decided that the topics contained in Section IV properly belonged in Section III), the median expected occurrence dates for only three items fell before 1980. All of the items in Sections III and IV (General Energy/Environment and Added Items) were expected from 1990 on, with three of the six expected after the year 2000. Six of the nine items in Section I and six of 13 items in Section II were expected during the decade 1980-1989, or nearly 43% of all 28 items. Two items from Section I and three from Section II had median expected occurrence dates after 2000. Only those topics contained in Section I, Air Quality Measuring/Monitoring and Section II, Air Quality Regulations/Control with median expected occurrence dates before 2000 were considered for purposes of future curriculum design. Within this time frame were 17 topic items, as summarized in Table 16.

Referring to Table 15, the event predicted by the Delphi panel with the earliest median expected occurrence date (1978) was item I-4a, Development and acceptance of reliable continuous monitoring equipment for...stationary sources. Two other items with median expected occurrence dates before 1980 were items II-2a and II-2b, Development and enactment of air quality...ambient standards for sulfates; and Development and enactment of air quality standards [for] particulates based on size. As noted before, 12 of 22 items in Sections I and II had median expected occurrence dates between 1980 and 1989, with the remaining five expected to occur (median) later than 2000.

TABLE 15

CHRONOLOGICAL ORDERING OF DELPHI PROJECTION ITEMS

Item	Event	Median Date of Occurrence
I 4a	Development and acceptance of reliable continuous monitoring equipment for continuous monitoring of stationary sources	1978
II 2a	Development and enactment of air quality standards (for) ambient standards for sulfates	1979
II 2b	Development and enactment of air quality standards (for) particulates based on size	1979
I 4b	Development and acceptance of reliable continuous monitoring equipment for non-methane hydrocarbons	1981
II 3	Pollution-free incineration of refuse for power generating capabilities	1983
I 1	Automatic/remote measurement systems using techniques such as lidar, laser, spectroscopic, or fluorescent-luminescent methods	1984
I 2	Continuous monitoring/mapping of air quality from satellites or high altitude aircraft	1984
II 5	Development of high temperature (1000^{o}F) baghouse fabric	1985
II 6	Control of smoke to non-visible or nearly non-visible plume conditions	1985
I 4d	Development and acceptance of reliable continuous monitoring equipment for heavy metals	1988
II 10a	Control/removal of SO_x emissions in all stationary sources	1988
II 10b	Control/removal of SO_x emissions in industry	1988
II 1	Development of nationwide air quality index	1989
I 3	Development and use of reliable continuous particulate counting equipment capable of making size separations	1989
I 4c	Development and acceptance of reliable continuous monitoring equipment for odor	1989
IV 1	Use of pyrolysis for energy production from refuse	1990
IV 2	Use of wind generators for limited energy applications	1992

TABLE 15 - continued

Item	Event	Median Date of Occurrence
II 9	Correlation of ambient levels with stack emissions so that air quality monitoring can be used to indicate allowable atmospheric loading	1993
II 10c	Control/removal of SO_x emissions in power plants	1995
III 1	Widespread use of "planned community" approach to urban planning, incorporating air quality aspects	2000
II 7	Coal gasification/desulfurization	2002
IV 3	Widespread electric power generation from solar energy	2004
II 4	Control of NO_x emissions (by process change or control technology)	2014
II 8	Development of a pollution-free source for individual transportation (hydrogen fuel cells, solar, i.c., etc.)	2015
III 3	Widespread use of hydrogen as a fuel	2020
I 4f	Development and acceptance of reliable continuous monitoring equipment for organics	2040
I 4e	Development and acceptance of reliable continuous monitoring equipment for all-pollutant, single-instrument, computer-controlled analyzers	2045
III 2	Development and use of urban mass transit systems	2240

TABLE 16

SUMMARY OF DELPHI TOPIC SECTION
MEDIAN EXPECTED DATES

Section	Total Number Items	Number of Items with Median Expected Date: Before 1980	Between 1980-1989	Between 1990-2000	Later than 2000
I	9	1	6	0	2
II	13	2	6	2	3
III & IV	6	0	0	3	3
Total	28	3	12	5	8

One purpose of this project was to attempt to determine the content of training programs for air pollution control technicians in the future. The modified Delphi project was undertaken to meet this objective. Based on the outcomes of the Delphi projections, several observations in the method should be noted. First, as has been discussed previously, few of the dates from round to round were changed by the Delphi panel members. Unless over half the panel members changed their estimate on any round, there was no change in the dates for that item. Second, almost none of the panel members expressed reasons for changing the dates which they had previously projected for specific events. Third, the Delphi technique was supposed to promote consensus among panel members as to the future time a given event is predicted to occur. The consensus was estimated by the interquartile range for each event: consensus was improved if the interquartile range decreased during progressive rounds. However, as shown in Table 13, with two exceptions, the interquartile ranges remained constant throughout the project.

The interquartile range for topic item II-1, Development of nationwide air quality index, was 25 years on the first two Delphi rounds. On the final round, changes in the latest expected date by panel members decreased the range to 23 years. Similarly, topic item II-10c, Control/removal of SO_x emissions in power plants, had an interquartile range of 120 years on the first round. On the second and third rounds, the range was reduced to 30 years. The narrowest range of two years was obtained for two topic items, II-2a and II-2b, Development and enactment of air quality...ambient standards for sulfates, and Development and enactment of air quality standards [for] particulates based on size, respectively. The widest range was 520 years for topic item III-2, Development and use of urban mass transit systems.

CHAPTER 4

DISCUSSION OF DATA

Technician Questionnaire

This study dealt with two aspects of curriculum design for air pollution technology training programs; an evaluation of topics to be included in present training curriculums and a projection of curriculum needs for training programs of the future.

For the first part of the project, a list of 104 topic items in air pollution control technology was prepared. The list was incorporated in a table with a relative scale of importance such that each topic item could be given a rating in terms of its value to an air pollution control technician. The checklists, or questionnaires, were sent to two groups of respondents. The first group consisted of 208 municipal, state and federal air pollution control agencies. The second group included 218 private firms including manufacturing industries and consulting firms. From government control agencies, 169 usable replies were received for a response rate of 81.3%. The private sector responded with 77 usable replies, a rate of 35.3%, for an overall combined response of 57.7%. Replies from each sector were tabulated and weighted values for each item were calculated. All replies were arranged in rank order of importance by respondent group, then placed in an overall rank order tabulation. Ten data tables were prepared, the last of which was a Spearman rank order correlation comparing replies from the two respondent groups.

A large difference was noted in the rate of return of the technician questionnaires for government agencies versus private firms. As shown in Table 1, 81.3% of the government agencies returned the completed questionnaire, while only 35.3% of the private firms contacted did so. Reasons for this large disparity are not obvious, but a possible explanation relates to the basic purposes of the two sectors. Government agencies engage in regulatory and enforcement activities, while industrial firms have been faced with compliance and related profit-oriented problems. Another possibility is that government agencies are more used to completing forms and submitting reports than industrial firms. Also, with increasing enforcement and control activity directed toward private industry in recent years, private firms may have become more suspicious of any attempts to gather information on their processes and air pollution control problems. One would hesitate to add a final possibility; that government control agencies are simply more cooperative and are more interested in solving the problems of air pollution control than are private firms.

Whatever the real reasons were for the large difference in response rate between the two groups, the fact that government agencies in general rated the various topic items higher than private firms had the effect of weighting the results to reflect the outlook and educational priorities held by the control agencies. This statement was borne out by the data presented in the various tables. Furthermore, as illustrated by the data presented in other tables, there was little doubt that quite different priorities in technician training were seen by the two groups. That there were differences in opinion between the two groups might be expected; that there was a low order of

correlation, or even no correlation, in terms of instructional objectives as seen by the two groups, might not be surprising. However, to discover that there was a strong negative correlation, and that correlation was significant at the .01 and .05 levels for several topic areas was, to the writer, quite surprising. It might prove to be quite enlightening, in a heuristic sense, to select a representative number of respondents from each category and conduct personal interviews in an attempt to determine why there is such a wide discrepancy between the priorities visualized by government control agencies versus private firms. Based only on the results of this study, one would be tempted to conclude that two different training programs were indicated; one to train technicians to work for private firms and another to train personnel for employment by government control agencies. However, in the opinion of the writer, this would not be a practical or realistic solution.

In using the various tables to determine curriculum content of technician training programs, two facts should be remembered: first, that over twice as many government control agencies responded to the questionnaire as did private firms; and second, that government control agencies rated nearly all curriculum topics higher than did the private sector. These comments should not be construed as implying there was anything wrong with the evaluations submitted by the government agencies; on the contrary, it is quite likely that since their primary missions concern surveillance, monitoring and enforcement activities, government control agencies may very well be in a better position to determine those topics most important to a technician training program. On the other hand, personnel in private firms who are responsible for pollution control efforts frequently have collateral duties, such that they are unable to

devote their full time to the control and abatement of air pollution emissions.

Another interesting revelation was contained in Table 3. The topic items under the category Source Sampling were rated the highest overall importance by government respondents. Private firms, by comparison, put this very important category at the bottom of the six categories in terms of overall importance. Government agencies placed the lowest importance on ambient sampling, a fact which was also rather interesting. It will also be noted from Table 3 that the order of rankings of the topic sections was the same for the "Overall" category as for the "Government" category. This was due to the fact the "Overall" was a weighted average; the greater number of government respondents maintained the topic categories in the same rank order as for the government replies alone.

After averaging individual questionnaire item replies received from the government and private groups so that the two groups could be compared, the items were ranked from highest to lowest for each group, according to the original categorical groupings. Those rankings were shown in Table 5. The individual items were then averaged between the two groups and again ranked from highest to lowest, as presented in Table 6. This table shows the individual topic items in order of the importance assigned to them by the respondents to the questionnaire. By studying this table, one can see that topics from the original categorical classifications were scattered throughout the tabulation. This observation takes on added significance when Table 8 is examined. One can see from this table that there was a decided unequal distribution of topics throughout the rankings. The category Control Methods and

Emission Surveys had 11 of 12 items listed in the upper half of the rankings. At the other end of the scale, five of 26 items in Ambient Sampling were ranked in the upper half, with the remaining 21 in the lower half. From these figures, it can be seen that certain subject areas were much more important to the respondents than others. The category Control Methods and Emission Surveys had a preponderence of its 12 items in the upper half of the rankings, as did the category General Air Pollution Information. Also, the section Meteorology had over half its items in the upper half of the rankings. Given, as noted in previous discussions, the origin and nature of the data, these observations were not too surprising. However, it was somewhat disconcerting to find that the topics contained in the category Source Sampling were rated in fourth place, overall. It was only somewhat less disconcerting to find that topics concerned with Ambient Sampling were found rated in sixth (and last) place in overall importance. From a general knowledge of the problems concerned with air pollution sampling and monitoring, it would be surmised that the topic areas Source Sampling and Ambient Sampling would have been much higher on the priority list.

Comparison of Table 8 with Table 3 revealed some apparent discrepancies. According to Table 3, the order of importance of topic sections was somewhat different from that indicated in Table 8. The relative order of importance of the topic sections General Air Pollution Information, Laboratory Analyses and Equipment, and Ambient Sampling remained unchanged in second, fifth and sixth places, respectively. However, the section Source Sampling was first in Table 3, but fourth in Table 8. The reason for these shifts was in the method of presentation of the data. Table 3 was the weighted overall average of all the questionnaire

responses, while Table 8 was derived from the rank order of all 104 questionnaire items.

Table 9 refined the data presented in Table 8 from topic distribution by halves to quartile distributions. This tabulation might serve the interested instructor or educational administrator in determining a cut-off point in the construction of a curriculum for this area.

Based on the questionnaire data obtained and previous discussions in this chapter, the following observations and conclusions seem warranted:

1. Government agencies as a group responded to the questionnaire to a much larger degree than did the private sector. Considering only the private sector, a better response was obtained from consulting firms (42.8%) than from manufacturing companies (34.5%). An attempt should be made to find out why this was so.

2. Some positive means of contacting industrial firms (other than mail-out questionnaires) should be devised so that this important sector will be represented in considerations of curriculum content for technician training programs.

3. The importance assigned to the various topic items in the technician curriculum questionnaire showed a large variation between government agency respondents and the private sector. A significant inverse statistical relationship was demonstrated in this study. Reasons for this divergence should be established, if possible.

4. Private firms assigned a lower average importance to individual questionnaire topic items than government agency respondents. The reason for this is unknown, but the situation should be investigated and resolved, if possible.

5. The results of this study could be used as the basis for

constructing the complete technical portion of a two-year technician training program in air pollution control technology.

Delphi Projections

The second part of this project involved a modified Delphi projection of future developments in air pollution control by a panel of experts. This panel of experts was chosen by applying criteria related to prominence in the air pollution control field. Although 40 experts were contacted in the first two rounds and 10 additional experts were added for the third round, only 22 individuals participated in one or more rounds. The experts represented private industry, government control agencies, consulting firms, university professors and others.

On the first round, respondents identified 25 expected developments in the air pollution control and energy/environment fields. Each event was accompanied by an estimate of the earliest and latest dates the individual expected that particular event would be realized. From all the replies, an overall tabulation of events was prepared, showing interquartile earliest and latest dates, as well as an overall median expected date for the realization of each event. This first round tabulation was returned to the panel members and they were asked to delete any earliest or latest dates they disagreed with, to insert the date they considered more realistic and to state reasons for any changes made.

On the second round, several panel members requested that additional items be added to the tabulation for evaluation by the entire panel, bringing the total number of items to 28. The second round was tabulated and any changes in earliest, latest or median dates were noted. The tabulations were then sent out for the third and final round. Following this round, the replies were again tabulated and final inter-

quartile earliest and latest, as well as median dates were determined. These results were presented in Table 13, along with interquartile ranges for all 28 events.

Interquartile ranges for the 28 events were arranged in groups from lowest to highest by section. These results were presented in Table 14. It was seen from this table that there was a higher percentage of items in Sections III and IV with interquartile ranges greater than 25 years than in Sections I and II. One possible explanation of this was that the panel felt more competent or confident in predicting those future developments dealing with air quality measuring/monitoring topics and air quality regulations/control concepts than with the broader (and more nebulous) area of general energy/environment type problems.

In Table 15, the individual Delphi topic items were ranked chronologically by median expected occurrence date. Table 16 summarized the median expected occurrence dates by section within several future time blocks.

It was found that few dates were changed from round to round by the Delphi panel. Also, almost none of the panel members stated reasons for changes in dates which they made. Degree of consensus by panel members, estimated by decreasing interquartile ranges between rounds, was not appreciably demonstrated by this study. Interquartile ranges for the various topic items varied from a low of two years to a high of 520 years.

Implications for air pollution technician training programs in the future were several. Before 1978-1979, training programs should be restructured to provide additional instruction in the operation and maintenance of various types of continuous monitoring equipment. Referring to Table 7, it will be seen that this item was not specifically

listed, though several topics did deal with various types of instrumentation. Students should also be trained to have a familiarity with legal terminology so that they can understand the various standards set for allowable air pollution levels. In Table 7, item F-15, Typical legislation-state government, was ranked 40th of all items and item F-14, Air pollution legislation-federal government, was ranked 55th. Before 1979, these items should be upgraded in importance in the technical curriculum.

Likewise from Table 7, items C-2, Particle size distribution; C-1, Particle counter; and C-6, Microscopic analyses, were ranked 74th, 87th and 95th, respectively. Based on the Delphi projections for events which have a median probability of occurring before 1980, these three topic items should be upgraded and given more emphasis in future curriculum designs.

The decade 1980-1989 contained median realization dates for 12 items. Of these, six items either directly or indirectly involved automatic or continuous monitoring equipment. The implications for future curriculum design were clear from these data. Technician training programs should place greater emphasis on the operation and maintenance of these kinds of monitoring devices. Stress should be placed on the fundamentals of electronics, electrochemical systems and pneumatic-electro-mechanical sensing devices.

The remaining six items were of a more diverse nature. Realization of methods for the pollution-free incineration of refuse for power generating capabilities (item II-3) implied an increase in emphasis on source testing techniques and apparatus as well as specific tests which might be especially appropriate to power generating plants using refuse

as a fuel.

Development of high temperature (1000^{o}F) baghouse fabric (item II-5), with a median expected occurrence date of 1985, would allow more common usage of this type of high efficiency control equipment. If this becomes the case, training programs should strengthen instruction in principles of filtration collectors (item E-3, rated 15th in Table 7), criteria for equipment selection (item E-1, rated 46th) and control by process or equipment change (item E-12, rated 48th).

Control of smoke to non-visible or nearly non-visible plume conditions (item II-6), with a median expected occurrence date of 1985, will necessitate increased emphasis on methods of determining plume opacity and related source sampling techniques as noted previously.

Item I-4d, Development and acceptance of reliable continuous monitoring equipment for heavy metals, with a median realization date of 1988, once again emphasized the continuing and future importance of instrumentation and automatic monitoring devices. It behooves instructors and administrators in this technical specialty to plan for extensive curriculum coverage of this topic area.

One of the most pervasive, reactive and damaging air pollutants is sulfur oxides. Two Delphi items dealing with the control of sulfur oxides also had median expected dates of 1988. These items were II-10a, Control/removal of SO_x emissions in all stationary sources; and item II-10b, Control/removal of SO_x emissions in industry. Technological competence to test for these compounds must be incorporated in the basic chemistry, source sampling, control and instrumentation courses.

The development of a nation-wide air quality index, predicted by the panel for a median realization date of 1989, will allow the comparison of air quality conditions for various parts of the country on a numerical or quantitative basis. This event should help in the education of the general population as to the large variances in air quality in different parts of the country, and possibly to help focus attention on the problem. In terms of air pollution technician training programs, graduates should be well versed in methods of testing, calculating and significance of such an index.

Another event with a median expected date of 1989 was item I-4c, Development and acceptance of reliable continuous monitoring equipment for odor. At present, the whole area of odor and odor control is a relatively elusive, subjective phenomenon. The more odorous chemicals, such as the organic sulfides and nitrogen compounds can achieve unbelievably offensive recognition at concentrations in the low parts per billion. The low concentrations at which these compounds can be offensive make detection and identification more difficult, and thus more difficult to control. Many of these compounds, with such distinctive and fitting names as putrescine and cadaverine, are decomposition products of protein. Thus, it is not surprising to find them around meat processing plants, slaughter houses and rendering plants. Implications for technician training programs again related to increased exposure and training in instrumentation and a reappraisal of priorities in the basic chemistry offerings.

The next two items predicted by the panel had median realization dates of 1990 and 1992, and both were from the section General Energy/ Environment. The first of these, predicted for 1990, was the use of

pyrolysis for energy production from refuse. The second, predicted for 1992, was the use of wind generators for limited energy applications. The reader is referred to the previous discussion of item II-3, Pollution-free incineration of refuse for power generating capabilities, which seemed also to pertain to the pyrolysis item in its general implications for training programs, with the addition that students should be trained in the technical concepts of pyrolysis.

The second of the two items, concerning wind generators, was slightly puzzling. It was not known what exactly the panel had in mind in predicting this event. Since windmills have been in operation in various parts of the world for centuries "for limited energy applications," it can only be surmised that the panel intended by this prediction electrical generation capabilities.

For 1993, the panel predicted, with median certainty, the realization of the correlation of ambient levels with stack emissions so that air quality monitoring could be used to indicate allowable atmospheric loading. Future training programs reflecting this event would contain instruction in meteorology with such topics as wind turbulence, mixing heights and diffusion from an air pollution source. A companion subject field to meteorology would again be instructional topics in instrumentation.

Item II-10c, Control/removal of SO_x emissions in power plants, with a median expected date of 1995, is directly related to the discussion of items II-10a and II-10b, above. Why portion II-10c of that general item had a median predicted occurrence date seven years later than the other two was not known for certain. One possible explanation related to the magnitude of the problem, with the large number and varying ages and

designs of existing fossil fuel-burning power plants.

Predicting the future is at best a risky and pitfall-strewn occupation, even with the guidance of experts in the field in which one is making predictions. The road of scientific discoveries is literally paved with "it can't be done!" and "impossible!" signs. The history of science is the more interesting because of these almost routine upsets of prevalent thinking. Almost every area of science has its share of skeptics and pessimists. Even more interesting is the fact that some of the most ardent die-hard skeptics have come from the ranks of the scientists themselves. The Delphi technique is a vehicle which attempts to project into and predict the future in a limited way, using people who supposedly are the most knowledgeable about the field being predicted. The further into the future one attempts to look, the more hazy things become. Therefore, the writer made an arbitrary decision to limit the discussion of future events and their specific implications for technician training programs to those events with a median realization date occurring before the year 2000.

Nine other items in the Delphi projections had median realization dates of 2000 or later (the latest median date was 2240). Some of these, at least to the writer, appeared no more complex or difficult of attainment than events with much earlier median realization dates. Instructors in technician training programs in the year 2000 are today (1974) probably either children or young adults, and most of their students are not yet born! The writer leaves to these future instructors and students the verification of the projections contained herein.

Summarizing the discussions contained in this section, the following observations and conclusions appear tenable:

1. The composition of the Delphi panel changed from round to round. How much effect, if any, this had on the results was not known. A Delphi project might be set up using two panels to consider the same topic. The membership of one panel could be allowed to vary through successive rounds as reported in this study. The other panel could be pursued more aggressively to minimize inter-round changes in composition or membership. The results could be analyzed to determine whether the interquartile ranges changed between successive rounds for one panel to a greater extent than the other. It can be perceived intuitively that there could be statistical difficulties with such a project.

2. One of the objectives of a Delphi projection is to gain consensus among the panel members in regard to when a specific event will occur in the future. Consensus is improved if the interquartile range decreases between successive rounds. As noted previously, consensus was not appreciably improved during the study, using this measure. Interquartile ranges did not change frequently between rounds because few panel members changed their estimates from round to round. Evidently, most panel members were satisfied with the original estimates and saw no reason to disagree.

3. Of those few panel members who changed their estimates from round to round, almost none offered reasons for these changes. At least two explanations can be advanced to account for this. First, it was possible that respondents simply did not want to take time to think out and state their reasons for changing estimates, even though such reasons were firmly fixed in their minds. Second, the panel members may not have had firm reasons, but were relying mainly on intuition or a "feel" for the event. A third possibility was panel members were influenced by

the other panel members and simply "went along" with dates already established.

4. Of 28 events predicted by the panel, 19 had median realization dates prior to the year 2000. These events covered a broad gamut of technological achievements and advances and were discussed in terms of implications for future training programs in air pollution control technology. Many of these had to do with improvements in automated devices with advanced instrumentation systems. The results of these Delphi projections can be used by instructors and administrators to prepare for changes in curriculum content as predicted by experts in the air pollution control field.

CHAPTER 5

SUMMARY

This study had two major purposes. The first was to evaluate the relative importance of various topics and areas of knowledge concerning air pollution control technology as determined by experts in the air pollution control community. The topics and competency areas were evaluated specifically as to their importance for two-year technician training programs.

The second purpose of the study was to determine the probable content of technician training programs of the future (or more specifically, to the end of this century). This look into the future was attempted by means of the Delphi technique, again using a select group of experts from the air pollution control community.

A list of the entire 104 topic items in overall rank order of importance was presented. From this list and the following discussion of topic areas, the technical portion of a two-year curriculum in air pollution control technology can be constructed.

Based on the combined opinions of respondents in government control agencies and private firms, the most important topic area for technician training programs at the present time was source sampling. The next most important area was found to be general air pollution information, closely followed by control methods and emission surveys. Topics in meteorology were rated in overall fourth place, followed by laboratory

analyses and equipment. In last place, and accorded the lowest overall order of importance, was the topic area concerned with ambient sampling.

The order of importance discussed above was the same for government control agencies as for the combined respondent group. Considering only the private sector responses, the order of priorities was slightly different. Respondents from private firms rated the topic areas laboratory analyses and equipment, ambient sampling, meteorology, control methods and emission surveys, and general air pollution information in that order, but very close to each other in importance. In last place, and somewhat lower in overall scoring than the first five groups, was the topic area source sampling.

From the foregoing discussion, and based upon the particular requirements, resources and capabilities of the individual educational institution, the technical portion of a two-year curriculum can be devised.

The Delphi projections reported in the study gave an indication of curriculum content of technician training programs in the future. According to these projections, the most important thrust of developing technology in the air pollution control field will be in the area of automatic remote detection and analysis equipment. Consequently, before 1980, administrators and instructors should take steps to introduce, upgrade and otherwise enhance instructional topic areas in the operation and maintenance of various automatic/remote continuous detection and analytical instruments.

The Delphi panelists also predicted an increase in the importance of legal terminology and an understanding of typical federal and state emission control statutes.

Also before 1980, certain laboratory analyses and operations will take on added significance. These topic areas should receive added emphasis in the curriculum.

In the decade beginning in 1980, topic items relating to continuous automatic monitoring devices were predicted for realization by the Delphi panel, again underscoring the importance of this area for future training programs. Several other topic areas were elucidated by the panel, in general emphasizing increased importance on source sampling and various types of air pollution control equipment.

During the last decade of the 20th century, several topics of a more general energy/environment nature were predicted by the Delphi panel, along with several specific analytical testing procedures.

Predictions having median realization dates in the 21st century were generally of a more diverse nature, relating to broad problems concerning the total environment. These predictions were not usually amenable to definition in terms of specific curriculum topics, and being further in the future, were consequently more uncertain as to realization. As corroboration for this statement, the final item predicted by the panel was the development and use of urban mass transit systems with a median expected realization date of 2240, or 266 years from now!

APPENDIX A

TECHNICIAN QUESTIONNAIRE: COVER LETTER, INSTRUCTIONS, CHECKLIST AND FOLLOW-UP LETTER

Cover Letter

Dear

Santa Fe Community College is engaged in a project to update its curriculum for training air pollution control technicians. We are trying to make the two-year program reflect the most widely-used testing and control techniques to ensure that graduates are valuable assets to those companies and agencies employing them. Students in the program receive training in the fundamentals of math, chemistry, physics and biology, in addition to specialized training in air pollution control and testing techniques.

We would greatly appreciate your assistance as one who has supervisory responsibility for technicians engaged in air pollution control or monitoring work. Would you please take a few minutes of your time to complete the attached check list?

A self-addressed envelope is enclosed for your convenience in mailing the form back to Santa Fe.

Thank you very much for your cooperation.

Very truly yours,

John M. Turner

Instructions

The following topics and test procedures are related to air pollution control and monitoring activities. In your estimation, which of these topics are of importance in the curriculum of a two-year technician training program?

Please place a checkmark in the "5" column for those concepts or procedures you feel are very important for a technician to know completely or be able to perform. Place a check in the "3" column for those items you think are fairly important but not absolutely essential for the technician to know. Check the "1" column for items you feel are of low importance and not necessary for the technician to know. Finally, use the "N/A" column for those tasks, concepts or procedures which are not applicable to your testing program or organization.

Have we missed any area or topics you feel should be included in such a training program? Please make a note of them under the section "Other important concepts or procedures".

Thank you very much for your cooperation.

Checklist

	Importance			
	Low 1	Moder-ate 3	High 5	N/A
A. Ambient Sampling				
1. Reasons for ambient sampling				
2. Sampling site selection criteria				
3. Determination of sample size required				
4. Physical properties of aerosols and particulates				
5. Principles of absorption				
6. Principles of adsorption				
7. Principles of grab sampling				
8. Principles of freezout sampling				
9. Principles of impinger operation				
10. Dustfall				
11. Suspended particulates - high vol method				
12. Soiling index - paper tape sampler				
13. Sticky tape samplers				
14. Sulfation rate - lead candle method				
15. Sulfation rate - sulfation plate method				
16. Corrosion plates				
17. Silver coated plates				
18. Fabric panels				
19. Rubber cracking strips				
20. Rotorod sampler				
21. Cascade impactors				
22. Anderson samplers				

Checklist

	Importance: Low 1	Moderate 3	High 5	N/A
23. Membrane filter				
24. Electrostatic precipitator				
25. Thermal precipitator				
26. MSA universal tester				
B. Source Sampling				
1. Objectives of testing				
2. Sampling site criteria				
3. Gas laws				
4. Measurement of pressure and temperature				
5. Gas velocity measurements				
6. Gas flow calculations				
7. Isokinetic sampling conditions				
8. Apparent molecular weight				
9. Sampling train components				
10. Orsat analyzer				
11. Smokescope				
12. Ringelmann chart				
13. Certification as smoke reader				
C. Laboratory Analyses and Equipment				
1. Particle counter				
2. Particle size distribution				
3. Use of desk calculators				

Checklist

	Importance: Low 1	Moderate 3	High 5	N/A
4. Use of digital computer				
5. Calculation, analysis and presentation of data				
6. Microscopic analyses				
7. Gas chromatograph				
8. Atomic absorption spectrophotometer				
9. Infrared absorption				
10. Ultraviolet absorption				
11. Emission spectroscopy				
12. SO_2 - pararosaniline (Photometric) method				
13. Sulfuric acid mist				
14. Hydrogen sulfide				
15. Carbon monoxide - NDIR method				
16. Oxidants - chemiluminescent method				
17. Oxidants - neutral buffered KI method				
18. Hydrocarbons - flame ionization method				
19. Organic acids				
20. Aldehydes				
21. NO_2 (Griess-Saltzman Reaction)				
22. NO_x				
23. Ammonia and ammonium compounds				
24. Fluorides				
25. Chlorides and chlorine compounds				
26. Lead				

Checklist

	Importance: Low 1	Moderate 3	High 5	N/A
D. Meteorology				
1. Psychrometry				
2. Wind speed and direction indicator				
3. Moisture content and dew point				
4. Wind turbulence and mixing heights				
5. Anemometers				
6. Lapse rates				
7. Evaporation and condensation				
8. Precipitation				
9. Movement of air masses and fronts				
10. Wind roses				
11. Diffusion from an air pollution source				

E. Control Methods and Emission Surveys				
1. Criteria for equipment selection				
2. Principles of mechanical collectors				
3. Principles of filtration collectors				
4. Principles of wet collectors				
5. Principles of electrostatic precipitators				
6. Gas absorption equipment				
7. Gas adsorption equipment				
8. Incineration, flame combustion				
9. Incineration, catalytic combustion				
10. Source emission inventories				

Checklist

	Importance Low 1	Moderate 3	High 5	N/A
11. Control by zoning				
12. Control by process or equipment change				

F. General Air Pollution Information

1. Definition of air pollution				
2. Classifications of air pollutants				
3. Historical aspects of air pollution				
4. General effects on atmosphere				
5. General effects on vegetation				
6. General effects on materials				
7. General effects on animals and human health				
8. Major national sources of air pollutants				
9. Major pollutants and levels of emission				
10. Air quality criteria				
11. Air quality standards				
12. Threshold limit values				
13. Characteristics of a control program				
14. Air pollution legislation - federal government				
15. Typical legislation - state government				
16. Atmospheric reactions of air pollutants				

Other important concepts or procedures:

Follow-up Letter

Dear

Several weeks ago, I sent you a letter concerning a research project I am conducting. Santa Fe is attempting to update its technician training program in air pollution technology. In order to do this, we need to know, from people who use air pollution control technicians, which testing procedures and abilities they consider to be the most valuable for a technician.

Will you please help us with this project? Check the list (which I sent with my first letter) as to those items you feel are very important, moderately important or of little importance and return to me.

If you have misplaced the checklist, I will be happy to send you another.

Thank you very much for your help.

Very truly yours,

John M. Turner

APPENDIX B

GOVERNMENT AGENCIES CONTACTED
FOR TECHNICIAN QUESTIONNAIRE
(*Indicates Usable Replies Received)

1. Alabama

(1)* Alabama Department of Health
Montgomery, Alabama

(2)* Jefferson County Department of Health
Birmingham, Alabama

2. Alaska

(3)* Cook Inlet Air Resources Management District
Anchorage, Alaska

(4)* Fairbanks North Star Borough
Fairbanks, Alaska

3. Arizona

(5)* Air Pollution Control Division
Phoenix, Arizona

(6)* Maricopa County Department of Health Services
Phoenix, Arizona

(7)* Pima County Air Pollution Control District
Tuscon, Arizona

4. Arkansas

(8)* Arkansas Department of Pollution Control and Ecology
Little Rock, Arkansas

5. California

(9) Environmental Systems Division
Van Nuys, California

(10)* Air Resources Board
Sacramento, California

5. California - continued

(11)* Bay Area Air Pollution Control District
San Francisco, California

(12)* Fresno County Public Health Department
Fresno, California

(13) Humboldt County Air Pollution District
Eureka, California

(14)* Inyo County Air Pollution Control District
Independence, California

(15)* Kern County Air Pollution Control District
Bakerfield, California

(16) Lassen County Air Pollution Control District
Susanville, California

(17)* Los Angeles County Air Pollution Control District
Los Angeles, California

(18)* Merced County Department of Public Health
Merced, California

(19)* Monterey-Santa Cruz County Unified Air Pollution
Control District
Salianas, California

(20)* Orange County Air Pollution Control District
Anaheim, California

(21)* Plumas County Health Department
Quincy, California

(22) Riverside County Air Pollution Control District
Riverside, California

(23)* Sacramento County Health Agency
Sacramento, California

(24)* San Bernardino County Air Pollution Control District
San Bernardino, California

(25)* San Diego County Air Pollution Control District
San Diego, California

(26) Sutter County Air Pollution Control District
Yuba City, California

(27)* Tulare County Air Pollution Control District
Visalia, California

(28) Ventura County Environmental Health Department
Ventura, California

6. Colorado

(29)* Colorado Department of Health
Denver, Colorado

(30)* Tri-County District Health Department
Englewood, Colorado

(31)* Denver Department of Health and Hospitals
Denver, Colorado

(32)* City-County Health Department
Colorado Springs, Colorado

(33)* Larimer County Health Department
Fort Collins, Colorado

(34)* Pueblo City-County Health Department
Pueblo, Colorado

(35)* Weld County Health Department
Greeley, Colorado

7. Connecticut

(36)* Department of Environmental Protection
Hartford, Connecticut

(37)* Greenwich Health Department
Greenwich, Connecticut

(38)* Department of Health
Meridan, Connecticut

(39) New Haven Health Department
New Haven, Connecticut

(40) Air Pollution Sanitarian
Department of Health
Norwalk, Connecticut

8. Delaware

(41)* Delaware Department of Natural Resources & Environmental Control
Dover, Delaware

9. Florida

(42)* Regional Administrator
Gulf Breeze, Florida

9. Florida - continued

(43)* Regional Administrator
Northeast Region
Jacksonville, Florida

(44) Regional Administrator
Central Region
Orlando, Florida

(45) Regional Administrator
West Central Region
Winter Haven, Florida

(46)* Regional Administrator
Southeast Region
Fort Lauderdale, Florida

(47)* Regional Administrator
Southwest Region
Punta Gorda, Florida

(48)* Broward County Pollution Control Board
Fort Lauderdale, Florida

(49)* Hillsborough County Environmental Protection Commission
Tampa, Florida

(50)* Department of Health, Welfare and Bio-Environmental Services
Jacksonville, Florida

(51)* Manatee County Health Department
Bradenton, Florida

(52)* Metropolitan Dade County Pollution Control Department
Miami, Florida

(53)* Palm Beach County Health Department
West Palm Beach, Florida

(54)* Department of Environmental Control
Sarasota, Florida

10. Georgia

(55)* Environmental Protection Division
Department of Natural Resources
Atlanta, Georgia

(56)* Fulton County Health Department
Atlanta, Georgia

11. Illinois

(57)* Environmental Protection Agency
Springfield, Illinois

(58)* City of Chicago Department of Environmental Control
Chicago, Illinois

(59)* Cook County Department of Environmental Control
Chicago, Illinois

12. Indiana

(60)* Indiana State Board of Health
Indianapolis, Indiana

(61)* Air Pollution Division
City of Gary
Gary, Indiana

(62)* Bureau of Air Pollution Control
Indianapolis, Indiana

13. Iowa

(63)* Air Quality Management Division
Iowa Department of Environmental Quality
Des Moines, Iowa

(64)* Des Moines-Polk County Health Department
Des Moines, Iowa

14. Kansas

(65)* Kansas State Department of Health
Topeka, Kansas

(66) Kansas City-Wyandotte County Department of Health
Kansas City, Kansas

(67)* Wichita-Sedgwick County Department of Community Health
Wichita, Kansas

15. Kentucky

(68)* Kentucky Department for Natural Resources and
Environmental Protection
Frankfort, Kentucky

(69)* Air Pollution Control District of Jefferson County
Louisville, Kentucky

16. Louisiana

(70)* Louisiana Health and Social Rehabilitation Services Administration
New Orleans, Louisiana

17. Maine

(71)* Department of Environmental Protection
Augusta, Maine

18. Maryland

(72)* Maryland State Department of Health and Mental Hygiene
Baltimore, Maryland

(73)* Allegany County Health Department
Cumberland, Maryland

(74)* Anne Arundel County Department of Health
Annapolis, Maryland

(75) Baltimore City Health Department
Baltimore, Maryland

(76)* Baltimore County Department of Health
Baltimore, Maryland

(77)* Montgomery County Department of Environmental Protection
Rockville, Maryland

19. Massachusetts

(78)* Bureau of Air Quality Control
Division of Environmental Health
Boston, Massachusetts

(79)* Central Massachusetts Air Pollution Control District
Worcester, Massachusetts

(80)* Merrimack Valley Air Pollution Control District
Tewksbury, Massachusetts

(81) Metropolitan Boston Interstate Air Pollution Control District
Boston, Massachusetts

(82) Pioneer Valley Air Pollution Control District
Springfield, Massachusetts

(83)* Southeastern Massachusetts Air Pollution Control District
Lakeville, Massachusetts

(84)* Worcester Department of Public Health
Worcester, Massachusetts

20. Michigan

(85)* Michigan Department of Natural Resources
Lansing, Michigan

(86)* Flint Air Pollution Control Division
Flint, Michigan

(87)* City of Grand Rapids Environmental Protection-Air Pollution Control
Grand Rapids, Michigan

(88)* Macomb County Health Department
Mt. Clemens, Michigan

(89)* Wayne County Health Department
Detroit, Michigan

21. Minnesota

(90)* Minnesota Pollution Control Agency
Minneapolis, Minnesota

(91) Department of Inspections
Air Pollution Control Division
Minneapolis, Minnesota

(92)* St. Cloud Health Department
St. Cloud, Minnesota

(93) St. Louis County Health Department
Duluth, Minnesota

(94)* St. Louis Park Health Department
St. Louis Park, Minnesota

(95) City of St. Paul
Air Pollution Control Division
St. Paul, Minnesota

22. Mississippi

(96)* Mississippi Air & Water Pollution Control Commission
Jackson, Mississippi

23. Missouri

(97)* Missouri Air Conservation Commission
Jefferson City, Missouri

(98)* Greene County-City of Springfield Air Pollution Control Authority
Springfield, Missouri

(99)* Kansas City Air Quality Division
Kansas City, Missouri

(100)* Division of Air Pollution Control
St. Louis, Missouri

(101)* St. Louis County Health Department
Clayton, Missouri

24. Montana

(102)* Montana State Department of Health and Environmental Sciences
Helena, Montana

25. Nebraska

(103)* Division of Air Pollution Control
Department of Environmental Control
Lincoln, Nebraska

(104)* Lincoln-Lancaster County Air Pollution Control Agency
Lincoln, Nebraska

(105)* Public Safety Department
City of Omaha
Omaha, Nebraska

26. Nevada

(106)* Bureau of Environmental Health
Carson City, Nevada

(107)* District Health Department of Clark County
Las Vegas, Nevada

(108)* Washoe County District Health Department
Reno, Nevada

27. New Hampshire

(109)* New Hampshire Air Pollution Control Agency
Concord, New Hampshire

28. New Jersey

(110)* Bureau of Air Pollution Control Agency
Trenton, New Jersey

(111)* Central Jersey Regional Air Pollution Control Agency
Woodbridge, New Jersey

(112) Department of Health, Welfare and Housing
Elizabeth, New Jersey

(113) Hudson Municipal Air Pollution Commission
Jersey City, New Jersey

(114)* Suburban Air Pollution Commission
West Orange, New Jersey

29. New Mexico

(115)* Environmental Improvement Agency
Santa Fe, New Mexico

(116)* Albuquerque Department of Environmental Health
Albuquerque, New Mexico

30. New York

(117)* New York State Department of Environmental Conservation
Albany, New York

(118)* Erie County Department of Health
Buffalo, New York

(119) Monroe County Department of Health
Rochester, New York

(120) Bureau of Air Pollution Control
Division of Environmental Health
Mineola, New York

(121) Environmental Protection Administration
City of New York
New York, New York

(122)* Interstate Sanitation Commission
New York, New York

(123)* Niagara County Health Department
Lockport, New York

(124)* Onondaga County Department of Health
Syracuse, New York

(125)* Rensselaer County Department of Health
Troy, New York

(126)* Rockland County Department of Health
Pomona, New York

(127) Suffolk County Department of Environmental Control
Hauppauge, New York

(128)* Westchester County Department of Health
White Plains, New York

31. North Carolina

(129)* Office of Water and Air Resources
Raleigh, North Carolina

(130)* Unifour Air Pollution Control Program
Newton, North Carolina

(131) Western North Carolina Regional Air Pollution Control Agency
Asheville, North Carolina

(132) Durham County Air Pollution Control Agency
Durham, North Carolina

(133)* Gaston County Health Department
Gastonia, North Carolina

(134)* Guilford County Department of Public Health
Greensboro, North Carolina

(135) Mechklenburg County Health Department
Charlotte, North Carolina

32. Ohio

(136)* Air Pollution Control
Akron, Ohio

(137)* Air Pollution Control Division
Canton City Health Department
Canton, Ohio

(138)* Air Pollution Control Division
Cincinnati, Ohio

(139)* Department of Public Health and Welfare
Cleveland, Ohio

(140)* Lake County Combined General Health District
Painesville, Ohio

(141)* Department of Air Pollution Control
Lorraine, Ohio

(142) Mahoning-Trumbull Air Pollution Control Agency
Youngstown, Ohio

(143)* Regional Air Pollution Control Agency
Dayton, Ohio

(144) Portsmouth City Health District
Portsmouth, Ohio

(145)* Pollution Control Agency
Toledo, Ohio

33. Oklahoma

(146)* Oklahoma State Department of Health
Oklahoma City, Oklahoma

(147)* Oklahoma City-County Health Department
Oklahoma City, Oklahoma

(148)* Tulsa City-County Health Department
Tulsa, Oklahoma

34. Oregon

(149)* Department of Environmental Quality
Portland, Oregon

(150)* Columbia-Willamette Air Pollution Region
Portland, Oregon

(151)* Lane Regional Air Pollution Authority
Eugene, Oregon

35. Pennsylvania

(152)* Bureau of Air Quality and Noise Control
Harrisburg, Pennsylvania

(153)* Bureau of Air Pollution Control
Pittsburgh, Pennsylvania

(154)* Philadelphia Department of Public Health
Philadelphia, Pennsylvania

36. Puerto Rico

(155)* Environmental Quality Board
Santurce, Puerto Rico

37. Rhode Island

(156)* Rhode Island Division of Air Pollution Control
Providence, Rhode Island

38. South Carolina

(157)* South Carolina Department of Health and Environmental Control
Columbia, South Carolina

(158)* Charleston County Health Department
Charleston, South Carolina

(159) Greenville County Health Department
Greenville, South Carolina

39. South Dakota

(160)* South Dakota Department of Environmental Protection
Pierre, South Dakota

40. Tennessee

(161)* Tennessee Department of Public Health
Nashville, Tennessee

(162)* Chattanooga-Hamilton County Air Pollution Control Bureau
Chattanooga, Tennessee

(163)* City of Memphis-Shelby County Health Department
Memphis, Tennessee

(164)* Metropolitan Health Department of Nashville and Davidson County
Nashville, Tennessee

(165)* Texas Air Control Board
Austin, Texas

(166)* Corpus Christi-Neuces County Department of Health and Welfare
Corpus Christi, Texas

(167)* City of Dallas Public Health Department
Dallas, Texas

(168)* El Paso City-County Health Unit
El Paso, Texas

(169)* Department of Public Health
Ft. Worth, Texas

(170) Galveston County Air Control Department
Texas City, Texas

(171) Pollution Control Department
Pasadena, Texas

(172)* Department of Public Health
City of Houston
Houston, Texas

(173) Jefferson County Environmental Control Department
Beaumont, Texas

(174)* San Antonio Metropolitan Health District
San Antonio, Texas

42. Utah

(175) Utah State Division of Health
Salt Lake City, Utah

43. Vermont

(176)* Agency of Environmental Conservation
Montepelier, Vermont

44. Virginia

(177)* State Air Pollution Control Board
Richmond, Virginia

(178)* Alexandria Health Department
Alexandria, Virginia

(179)* Fairfax County Air Pollution Control
Fairfax, Virginia

(180)* Air Pollution Control Bureau
Department of Public Safety
Richmond, Virginia

(181)* Roanoke County Health Department
Salem, Virginia

45. Washington

(182)* Washington State Department of Ecology
Olympia, Washington

(183)* Air Pollution Control Authority
Richmond, Washington

(184)* Northwest Air Pollution Authority
Mt. Vernon, Washington

(185)* Olympia Air Pollution Control Authority
Olympia, Washington

(186)* Puget Sound Air Pollution Control Agency
Seattle, Washington

(187) Southwest Air Pollution Control Authority
Van Couver, Washington

46. West Virginia

(188)* West Virginia Air Pollution Control Commission
Charleston, West Virginia

47. Wisconsin

(189)* Wisconsin Department of Natural Resources Bureau of Air Pollution
Madison, Wisconsin

(190)* Eau Claire City-County Health Department
Eau Claire, Wisconsin

(191)* Madison Department of Public Health
Madison, Wisconsin

(192)* Department of Air Pollution Control
Milwaukee, Wisconsin

48. U. S. Government Agencies

(193)* Region I
Air & Water Programs Division
Boston, Massachusetts

(194)* Region II
Air Programs Branch
New York, New York

(195) Region III
Program Development Section
Philadelphia, Pennsylvania

(196)* Region IV
Regional Air Pollution Center
Atlanta, Georgia

(197)* Region V
Regional Air Pollution Control
Chicago, Illinois

(198)* Region VI
Air & Water Programs Division
Dallas, Texas

(199)* Region VII
Air Program Support Branch
Kansas City, Missouri

(200) Region VIII
Regional Air Pollution Control
Denver, Colorado

(201) Region IX
Air & Water Programs Division
San Francisco, California

(202)* Region X
Air Programs Branch
Seattle, Washington

49. <u>Foreign Government Agencies</u>

(203)* Air Pollution Control Directorate
Environmental Protection Service
Ottawa, Ontario, Canada

(204)* Environmental Management Division
Winnipeg, Manitoba, Canada

(205)* Ministry of the Environment
Toronto, Ontario, Canada

(206)* Environmental Protection Services
Quebec, Canada

(207) The Air Purification and Food Inspection Department
Montreal 129, Quebec, Canada

(208) Saskatchewan Department of the Environment
Regina, Saskatchewan, Canada

APPENDIX C

LARGEST AIR POLLUTION SOURCES FOR INDUSTRY AND PROCESSING CATEGORIES

1. Electric power generation
2. Iron-steel production
3. Petroleum refining
4. Carbon black production
5. Rock crushing
6. Copper production
7. Organic solvents
8. Pulp-paper industry
9. Grain handling
10. Coking
11. Cement production
12. Lime production
13. Zinc and lead production
14. Natural gas liquid
15. Ammonia production
16. Asphalt batching
17. Sulfuric acid manufacturing
18. Photochemicals production
19. Aluminum production
20. Nitric acid production

Source: Cavender, James H.; Kircher, David S.; and Hammerle, James R. "Nationwide Air Pollutant Emission Trends, 1940-1970", p. 66-70. Research Triangle Park, N.C.: U. S. Environmental Protection Agency. August, 1972.

APPENDIX D

PRIVATE INDUSTRIAL AND CONSULTING FIRMS CONTACTED FOR TECHNICIAN QUESTIONNAIRE
(*Indicates Usable Replies Received)

1. <u>Electric Power Generation</u>

(1) Potomac Electric Power Company
Washington, D.C.

(2)* Florida Power and Light Company
Miami, Florida

(3) Commonwealth Edison Company
Chicago, Illinois

(4)* Boston Edison Company
Boston, Massachusetts

(5)* New Jersey Power and Light Company
Morristown, New Jersey

(6)* Tennessee Valley Authority
Knoxville, Tennessee

(7) Ohio Edison Company
Akron, Ohio

(8)* Georgia Power Company
New York, New York

(9)* Appalachian Power Company
New York, New York

(10) Consolidated Edison
New York, New York

2. & 10. <u>Iron-Steel Production</u>
<u>Coking</u>

(11)* U.S. Steel Corporation
Gary, Indiana

(12)* Bethlehem Steel Company
Bethlehem, Pennsylvania

(13)* Republic Steel Corporation
Pittsburgh, Pennsylvania

(14)* Armco Steel Corporation
Middletown, Ohio

(15)* National Steel Corporation
Pittsburgh, Pennsylvania

(16) Inland Steel Company
East Chicago, Indiana

(17)* Jones and Laughlin Steel
Pittsburgh, Pennsylvania

(18) Youngstown Sheet and Tube
New Orleans, Louisiana

(19) Allegheny Ludlum Steel Corporation
Pittsburgh, Pennsylvania

(20) Harsco Corporation
Camp Hill, Pennsylvania

(21)* Esco Corporation
Portland, Oregon

(22) Crucible Steel Company of America, Incorporated
Pittsburgh, Pennsylvania

3. Petroleum Refining

(23)* Union Oil of California
Los Angeles, California

(24)* Standard Oil Company of California
San Francisco, California

(25)* Ashland Oil Incorporated
Ashland, Kentucky

(26)* Mobil Oil Corporation
New York, New York

(27)* Quaker State Oil Refining Corporation
Oil City, Pennsylvania

(28)* Gulf Oil Corporation
Pittsburgh, Pennsylvania

(29) Humble Oil and Refining Company
Houston, Texas

(30)* Texaco Incorporated
Beacon, New York

(31)* Sun Oil Company
Philadelphia, Pennsylvania

(32) American Petrofina Incorporated
New York, New York

(33)* The Lubrizol Corporation
Cleveland, Ohio

(34) Fiske Brothers Refining Company
Newark, New Jersey

4. Carbon Black Production

(35)* Cabot Corporation
Boston, Massachusetts

(36)* J.M. Huber Corporation
Locust, New Jersey

(37) Commercial Solvents Corporation
New York, New York

(38)* Carbon and Gasline
Ft. Worth, Texas

(39)* Continental Carbon Company
Houston, Texas

(40) Texas Foundries Incorporated
Lufkin, Texas

5. Rock Crushing

(41) Consolidated Rock Products Company
Los Angeles, California

(42) York Hill Trap Rock Quarry Company
Meriden, Connecticut

(43) Pacific Concrete and Rock Company
Honolulu, Hawaii

(44) E.I. Sargent Quarries, Incorporated
Des Moines, Iowa

(45) Rockville Crushed Stone, Incorporated
Baltimore, Maryland

(46) Rock Hill Quarries Company
St. Louis, Missouri

(47) Crushing Stone Company
Schenectady, New York

(48) Palmetto Quarries Company
Columbia, South Carolina

(49) Basalt Rock Company
Napa, California

(50) Roncari Industries, Incorporated
East Granby, Connecticut

(51)* General Crushed Stone, Incorporated
Easton, Pennsylvania

(52) The Carborundum Company, Incorporated
Niagra Falls, New York

6. Copper Production

(53) Anaconda Company
New York, New York

(54)* Phelps Dodge Refining Corporation
Flushing, New York

(55) Cerro Corporation
New York, New York

(56) Southern Peru Copper Corporation
New York, New York

(57) White Pine Copper Company
New York, New York

(58) Barth Smelting and Refining Company
Newark, New Jersey

(59) Rochester Smelting & Refining Company
Rochester, New York

(60) Pyrites Company
Wilmington, Delaware

(61) Okonite Company
Passaic, New Jersey

7. Organic Solvents

(62) U.S.I. Chemicals
New York, New York

(63) Union Carbide Corporation
New York, New York

(64) PPG Industries, Incorporated
Pittsburgh, Pennsylvania

(65) Union Oil Company of California
Palatine, Illinois

(66) Fine Organics, Incorporated
Lodi, New Jersey

(67) Celanese Chemical Company
New York, New York

(68) Caig Laboratories, Incorporated
Westburg, New York

(69) Eastman Chemical Products, Incorporated
Kingsport, Tennessee

(70) Ketona Chemical Corporation
Birmingham, Alabama

(71)* Collier Carbon and Chemical Corporation
Los Angeles, California

(72)* Uniroyal, Incorporated
Naugatuck, Connecticut

(73)* Sherwin-Williams Company, Incorporated
Cleveland, Ohio

(74) Valspar Corporation
Rockford, Illinois

(75) Englehard Minerals and Chemicals
Newark, New Jersey

(76)* Morton International Incorporated
Chicago, Illinois

(77)* Ferro Corporation
Cleveland, Ohio

(78)* U.S. Borax and Chemicals
Los Angeles, California

(79) Penn Corporation
Butler, Pennsylvania

8. <u>Pulp-Paper Industry</u>

(80)* St. Joe Paper Company
Jacksonville, Florida

(81) Gilman Paper Company
New York, New York

(82)* International Paper Company
New York, New York

(83)* ITT Rayonier, Incorporated
New York, New York

(84) Mead Corporation
Dayton, Ohio

(85) Hudson Pulp and Paper Corporation
New York, New York

(86)* St. Croix Paper Company
Portland, Oregon

(87)* Scott Paper Company
Philadelphia, Pennsylvania

(88) Kimberly Clark Corporation
Neenah, Wisconsin

(89)* St. Regis Paper Company
New York, New York

(90)* Brunswick Pulp and Paper
Brunswick, Georgia

(91) Hammerhill Paper Company, Incorporated
Erie, Pennsylvania

(92) Container Corporation of America
Chicago, Illinois

(93)* Owens-Corning Fiberglass
Toledo, Ohio

9. <u>Grain Handling</u>

(94) N. F. Davis Drier & Elevator Company
Firebaugh, California

(95) Northwestern Malt and Grain Company
Minneapolis, Minnesota

(96) Davis-Noland-Merill Grain Company
Kansas City, Missouri

(97) Union Equity Co-Op Exchange
Enid, Oklahoma

(98) Hillcrest Farms
Andalusia, Alabama

(99) Coleman, E.R. Farms and Elevator
Dowdy, Arkansas

(100) Farmers Grain Dealers
Des Moines, Iowa

(101) Baker Grain, Incorporated
Ridgeville, Indiana

(102) Becks Superior Hybrids
Atlanta, Georgia

11. Cement Production

(103)* American Cement Corporation
Los Angeles, California

(104) California Portland Cement Company
Los Angeles, California

(105)* Kaiser Cement and Gypsum Corporation
Oakland, California

(106) Louisville Cement Company
Louisville, Kentucky

(107)* Oregon Portland Cement Company
Portland, Oregon

(108) Ideal Cement Company
Denver, Colorado

(109)* Atlantic Cement Company
Stamford, Connecticut

(110) Marquette Cement Manufacturing Company
Chicago, Illinois

(111) Arkansas Cement Corporation
Shreveport, Louisiana

(112) Ash Grove Cement Company
Kansas City, Missouri

12. Lime Production

(113) Lone Star Cement Corporation
Greenwich, Connecticut

(114) Southern Materials Corporation
Ocala, Florida

(115) Georgia Marble Company
Atlanta, Georgia

(116) Dolomite Products Company
Rochester, New York

(117)* Calcite Quarry Corporation
Lebanon, Pennsylvania

(118) Brooksville Rock Company
Brooksville, Florida

(119) Mississippi Lime Company
Alton, Illinois

(120) Columbia Quarry Company
St. Louis, Missouri

(121) East Ohio Limestone Company
Hartville, Ohio

13. Zinc and Lead Production

(122)* American Metal Climax Incorporated
New York, New York

(123)* New Jersey Zinc Company
Bethlehem, Pennsylvania

(124)* Bunker Hill Company
Kellogg, Idaho

(125) American Zinc Company
St. Louis, Missouri

(126) Matthiessen & Hegeler Zinc Company
La Salle, Illinois

(127) Murph Metals Incorporated
Dallas, Texas

(128) National Zinc Company
New York, New York

(129) Schuylkill Metals Corporation
Baton Rouge, Louisiana

(130) Victory White Metal Company
Cleveland, Ohio

(131) American Cyanamid Company, Incorporated
Wayne, New Jersey

(132)* Carpenter Technological Corporation
Reading, Pennsylvania

14. Natural Gas Liquid

(133) Atlanta Gas Light Company
Atlanta, Georgia

(134)* Citizens Gas and Coke Utility
Indianapolis, Indiana

(135)* Boston Gas Company
Boston, Massachusetts

(136) Michigan Consolidated Gas Company
Detroit, Michigan

(137) Gas Service Incorporated
Nashua, New Hampshire

(138) North Carolina Natural Gas Corporation
Fayetteville, North Carolina

(139) Pennsylvania Gas and Water Company
Wilkes Barre, Pennsylvania

(140) Providence Gas Company
Providence, Rhode Island

(141) Pyrofax Gas Corporation
Houston, Texas

(142) Wisconsin Fuel and Light Company
Manitowac, Wisconsin

15. Ammonia Production

(143)* Union Carbide Corporation
South Charleston, West Virginia

(144)* Allied Chemical Corporation
Morristown, New Jersey

(145)* Air Reduction Company, Incorporated
Montvale, New Jersey

(146)* Chemetron
Chicago, Illinois

(147) Air Products and Chemicals
Trexlertown, Pennsylvania

(148) Liquid Carbonic
Chicago, Illinois

(149) Big Three Industrial Gas Company
Houston, Texas

(150) Escambia Chemical Corporation
Pensacola, Florida

(151) Puritan Bennet Corporation
Kansas City, Missouri

(152) GASPRO
Honolulu, Hawaii

(153)* Filtrol Corporation
Los Angeles, California

16. Asphalt Batching

(154) Celotex Corporation
Tampa, Florida

(155) Mastic Corporation
South Bend, Indiana

(156) Flintkote Company
White Plains, New York

(157) Allied Materials Corporation
Oklahoma City, Oklahoma

(158) Bear Brand Roofing, Incorporated
Bearden, Arkansas

(159) Trumbull Asphalt Company of Deleware
Argo, Illinois

(160) Tamko Asphalt Products, Incorporated
Joplin, Missouri

(161) Johns Manville Products Corporation
New York, New York

(162) Panacon Corporation
Cincinnati, Ohio

(163) Certain-Teed Products Corporation
Ardmore, Pennsylvania

(164) Tremco Manufacturing Company, Incorporated
Cleveland, Ohio

(165) U.S. Gypsum Company
Chicago, Illinois

17. & 18. Sulfuric Acid Manufacturing
Photochemicals Production

(166) Wittichen Chemical Company
Birmingham, Alabama

(167) Collier Carbon and Chemical Corporation
Los Angeles, California

(168) American Cyanamid Company
Wayne, New Jersey

(169)* Olin Corporation
Stamford, Connecticut

(170)* Ashland Chemical Company
Columbus, Ohio

(171)* Arco Chemical Company
Philadelphia, Pennsylvania

(172) Koppers Company, Incorporated
Pittsburgh, Pennsylvania

(173) Robertson Chemical Corporation
Norfolk, Virginia

(174) McKesson Chemical Company
New York, New York

(175) Goodrich-Gulf Chemicals
Cleveland, Ohio

(176) General Alloys Company, Incorporated
South Boston, Massachusetts

(177) Clement Brothers Company, Incorporated
Hickory, North Corolina

19. Aluminum Production

(178) Reynolds Metals Company
Richmond, Virginia

(179)* Kaiser Aluminum and Chemical Corporation
Oakland, California

(180) Howmet Corporation
Greenwich, Connecticut

(181) Easco Corporation
Baltimore, Maryland

(182) Harvey Aluminum
Torrance, California

(183) Ormet Corporation
Stamford, Connecticut

(184) Consolidated Aluminum Corporation
Jackson, Tennessee

(185) Michigan Standard Alloys
Benton Harbor, Michigan

(186)* Capital Products Corporation
Mechanicsburg, Pennsylvania

(187) V.A.W. of America, Incorporated
Ellenville, New York

(188)* Aluminum Company of America
Pittsburgh, Pennsylvania

(189)* Anaconda Aluminum Company
Louisville, Kentucky

(190)* Alcan Aluminum Ltd.
Cleveland, Ohio

20. Nitric Acid Production

(191) du Pont E I de Nemours and Company, Incorporated
Wilmington, Delaware

(192) Kraft Chemical Company
Chicago, Illinois

(193) American Oil and Supply Company
Newark, New Jersey

(194)* Celanese Chemical Company
New York, New York

(195) Sohio Chemical Company
Lima, Ohio

(196) Berg Chemical Company, Incorporated
New York, New York

(197) U.S. Industrial Chemicals Company
New York, New York

21. Private Consulting Firms

(198)* Aero Vironment, Incorporated
Pasadena, California

(199)* Kaman Sciences Corporation
Colorado Springs, Colorado

(200) Pollution Research and Control Corporation
Glendale, California

(201)* Truesdail Laboratories, Incorporated
Los Angeles, California

(202)* TRW-Environmental Services
Redondo Beach, California

(203) Air Resources, Incorporated
Palatine, Illinois

(204) George D. Clayton and Associates
Southfield, Michigan

(205) Environmental Research, Incorporated
Cincinnati, Ohio

(206) Industrial Hazard Analysts Incorporated
Skokie, Illinois

(207) Midwest Environmental Management, Incorporated
Maumee, Ohio

(208)* Houston Environmental Control Corporation
Houston, Texas

(209) Resource Consultants, Incorporated
Nashville, Tennessee

(210) The Rust Engineering Company
Birmingham, Alabama

(211)* Betz Environmental Engineers, Incorporated
Plymouth Meeting, Pennsylvania

(212)* Ralph Hennig Associates
Cos Cob, Connecticut

(213) International Testing Laboratories, Incorporated
Newark, New Jersey

(214) Newark Environmental Control Corporation
Clifton, New Jersey

(215) Penn Environmental Consultants, Incorporated
Pittsburgh, Pennsylvania

(216)* Princeton Chemical Research, Incorporated
Princeton, New Jersey

(217)* Walden Research Corporation
Cambridge, Massachusetts

(218) Environmental Science and Engineering, Incorporated
Gainesville, Florida

APPENDIX E

MODIFIED DELPHI PROJECT: LETTER TO ORIGINAL DELPHI PANEL, FOLLOW-UP LETTER, COVER LETTER WITH SECOND ROUND, SECOND ROUND, COVER LETTER WITH FINAL ROUND, FINAL ROUND, AND LETTER OF INVITATION TO ADDED PANEL MEMBERS

Letter to Original Delphi Panel

Dear

As a person deeply involved in the problems of air pollution control, you have undoubtedly given much thought to what the future holds for control and abatement efforts. This is probably especially so in the last six months, since the energy crisis has added a new series of questions to the existing complex interaction of social, financial, legal and technological problems.

Your involvement and expertise in the problems of air pollution control give you an insight into future developments which few other people possess. Would you be willing to share your concept of the future with others? There is a way to do this which is quite interesting; it's called the Delphi technique. Briefly, it's a type of "brainstorming" developed some years ago by a group of Rand Corporation researchers: a group of experts in a given field are asked to compile a list of advances or developments they think will take place in that field in the future. For each individual item, an estimate of the earliest and latest dates that specific development might be expected is also made. The times estimated might be anywhere from a month to a century. The individual lists are collated and tabulation of earliest and latest dates is prepared from all respondents. The composite list is then sent back to the individual group members so that they can compare their estimates with those of the total group. If they wish, they may revise their estimates and give reasons for their own projections. Each participant remains anonymous from other group members during the project (so that no one will be unduly influenced by another individuals' opinion). To my knowledge, the technique has never been applied to the field of air pollution control, but papers describing the results achieved in other areas reveal some very interesting and useful results.

To start the project, please list as many new developments or advances of whatever kind in the field of air pollution control and monitoring you feel will have an effect on control and abatement efforts. These might include legal or social developments as well as technological or engineering advances. For each item, put the earliest date (month or

year) and the latest date you estimate will take to realize that particular development. This is a form of "crystal ball gazing", so please give full rein to your imagination, because this is the way some really useful information is brought to light by people expert in the field. Hopefully, your list will contain no less than 10 items, but please put as many as you can think of. I will collate all replies showing the earliest, latest and median dates for each item and return them to you.

As an example, the following item <u>might</u> show up as an expected development in the field:

Expected Development	Date Expected	
	Earliest	Latest
Nation-wide use of automatic exhaust samplers for vehicular air pollution sources, with built-in analytical and data print-out equipment.	1980	2000

Can you please have your list of items and dates back to me by March 15? I hope you can find time to participate in this interesting venture.

Thank you.

Very truly yours,

John M. Turner

Follow-up Letter

Dear

On February 18, I wrote to you asking for your help on a research project I am conducting. This project involves using the Delphi technique to predict future developments in air pollution control. For the technique to produce meaningful insights, a broad representative group of experts in the field must state their views as to what they think the future will hold for air pollution control efforts.

Will you please help me in this project? Jot down as many developments in the field as you can think of, put an earliest and latest date you think it will take to realize each development and send it to me. I'll summarize all the opinions (omitting names of individual respondents) and send you the tabulated "crystal ball" results for your reaction.

Thanks for your help.

Best regards,

John M. Turner

Cover Letter With Second Round

Dear

Thank you for your response to my letter concerning projected developments in the field of air pollution control.

The responses showed a great deal of imagination and thoughtfulness. I have attempted to arrange the responses by category, and by slight rewording collect similar thoughts into single future projections, where possible. The attached list represents the summary of future projections by the expert panel. I hope I have retained the idea of your projections in this list.

You will note that I have grouped the items into three broad classifications: (1) Air Quality Measuring/Monitoring, (2) Air Quality Regulations/Control and (3) General Energy/Environment. I have included the earliest, latest and median occurrence dates estimated by the panel.

If you disagree with either the earliest or latest date for any item, cross out the date you disagree with and write in, on the line below it, the date you think is more realistic. Remember, you can insert either an earlier or later EARLIEST date and an earlier or later LATEST date. If you wish, you can include a note as to why you are changing the date for that event.

If you agree with all dates listed, please note your agreement.

Please return your revised list to me as soon as possible. I will note any changes in expected dates, recalculate medians and inform you of the results.

Thank you for your cooperation.

Very truly yours,

John M. Turner

Second Round

DELPHI PROJECTIONS

I. Air Quality Measuring/Monitoring

1. Automatic/remote measurement systems using techniques such as lidar, laser, spectroscopic, or fluorescent-luminescent methods:

EARLIEST	LATEST	MEDIAN
1977	1990	1984
____	____	

2. Continuous monitoring/mapping of air quality from satellites or high altitude aircraft:

EARLIEST	LATEST	MEDIAN
1978	1990	1984
____	____	

3. Development and use of reliable continuous particulate counting equipment capable of making size separations:

EARLIEST	LATEST	MEDIAN
1978	2000	1989
____	____	

4. Development and acceptance of reliable continuous monitoring equipment for the following pollutant sources-types:

   a. Continuous monitoring of stationary sources

EARLIEST	LATEST	MEDIAN
1975	1980	1978
____	____	

   b. Non-methane hydrocarbons

EARLIEST	LATEST	MEDIAN
1978	1983	1981
____	____	

c. Odor

EARLIEST	LATEST	MEDIAN
1978	2000	1989
____	____	

d. Heavy metals

EARLIEST	LATEST	MEDIAN
1975	2000	1988
____	____	

e. All-pollutant, single-instrument, computer-controlled analyzers

EARLIEST	LATEST	MEDIAN
1990	2100	2045
____	____	

f. Organics

EARLIEST	LATEST	MEDIAN
1980	2100	2040
____	____	____

II. Air Quality Regulations/Control

1. Development of nation-wide air quality index:

EARLIEST	LATEST	MEDIAN
1975	2000	1988
____	____	

2. Development and enactment of air quality standards:

a. Ambient standards for sulfates

EARLIEST	LATEST	MEDIAN
1978	1980	1979
____	____	

b. Particulates based on size.

EARLIEST	LATEST	MEDIAN
1978	1980	1979
____	____	

3. Pollution-free incineration of refuse for power generating capabilities:

EARLIEST	LATEST	MEDIAN
1975	1990	1983
____	____	

4. Control of NO_x emissions (by process change or control technology)

EARLIEST	LATEST	MEDIAN
1978	2050	2014
____	____	

5. Development of high temperature (1000^o) baghouse fabric:

EARLIEST	LATEST	MEDIAN
1980	1990	1985
____	____	

6. Control of smoke to non-visible or nearly non-visible plume conditions:

EARLIEST	LATEST	MEDIAN
1980	1990	1985
____	____	

7. Coal gasification/desulfurization:

EARLIEST	LATEST	MEDIAN
1979	2026	2002
____	____	

8. Development of a pollution-free power source for individual transportation (hydrogen fuel cells, solar, i.c., etc.)

EARLIEST	LATEST	MEDIAN
1980	2050	2015
____	____	

9. Correlation of ambient levels with stack emissions so that air quality monitoring can be used to indicate allowable atmospheric loading:

EARLIEST	LATEST	MEDIAN
1985	2000	1993
____	____	

10. Control/removal of SO_x emissions in:

    a. All stationary sources

EARLIEST	LATEST	MEDIAN
1976	2000	1988
____	____	

    b. Industry

EARLIEST	LATEST	MEDIAN
1980	1995	1988
____	____	

    c. Power plants

EARLIEST	LATEST	MEDIAN
1980	2100	2040
____	____	

III. General Energy/Environment

1. Widespread use of "planned community" approach to urban planning, incorporating air quality aspects:

EARLIEST	LATEST	MEDIAN
1974	2025	2000
____	____	

2. Development and use of urban mass transit systems:

EARLIEST	LATEST	MEDIAN
1980	2500	2240

3. Widespread use of hydrogen as a fuel:

EARLIEST	LATEST	MEDIAN
1990	2050	2020

Cover Letter with Final Round

Dear

Attached is the FINAL ROUND of the Delphi Forecast of future developments in air pollution control. As in previous rounds, the earliest, latest and median dates, as estimated by the expert panel, are listed for each event.

On the final page of the tabulation, you will note a section titled Added Items. These three items have been added to the original list of projections by panel members during the previous round. The panel members urged that these items be evaluated in the final round by the full panel.

Please review the attached tabulation and change any of the EARLIEST or LATEST dates with which you disagree. If you agree with the dates as presented, simply note your agreement and return the tabulation to me at your earliest convenience.

In the interest of bringing the project to a conclusion, can I please have your completed tabulations by September 16?

Thank you again for your interest and cooperation.

Very truly yours,

John M. Turner

Final Round

DELPHI PROJECTIONS

I. Air Quality Measuring/Monitoring

1. Automatic/remote measurement systems using techniques such as lidar, laser, spectroscopic, or fluorescent-luminescent methods:

EARLIEST	LATEST	MEDIAN
1977	1990	1984

2. Continuous monitoring/mapping of air quality from satellites or high altitude aircraft:

EARLIEST	LATEST	MEDIAN
1978	1990	1984

3. Development and use of reliable continuous particulate counting equipment capable of making size separations:

EARLIEST	LATEST	MEDIAN
1978	2000	1989

4. Development and acceptance of reliable continuous monitoring equipment for the following pollutant sources-types:

a. Continuous monitoring of stationary sources

EARLIEST	LATEST	MEDIAN
1975	1980	1978

b. Non-methane hydrocarbons

EARLIEST	LATEST	MEDIAN
1978	1983	1981

c. Odor

EARLIEST	LATEST	MEDIAN
1978	2000	1989
____	____	

d. Heavy metals

EARLIEST	LATEST	MEDIAN
1975	2000	1988
____	____	

e. All-pollutant, single-instrument, computer-controlled analyzers

EARLIEST	LATEST	MEDIAN
1990	2100	2045
____	____	

f. Organics

EARLIEST	LATEST	MEDIAN
1980	2100	2040
____	____	

II. Air Quality Regulations/Control

1. Development of nation-wide air quality index:

EARLIEST	LATEST	MEDIAN
1975	2000	1988
____	____	

2. Development and enactment of air quality standards:

a. Ambient standards for sulfates

EARLIEST	LATEST	MEDIAN
1978	1980	1979
____	____	

b. Particulates based on size

EARLIEST	LATEST	MEDIAN
1978	1980	1979
____	____	

3. Pollution-free incineration of refuse for power generating capabilities:

EARLIEST	LATEST	MEDIAN
1975	1990	1983
____	____	

4. Control of NO_x emissions (by process change or control technology):

EARLIEST	LATEST	MEDIAN
1978	2050	2014
____	____	

5. Development of high temperature ($1000^{o}F$) baghouse fabric:

EARLIEST	LATEST	MEDIAN
1980	1990	1985
____	____	

6. Control of smoke to non-visible or nearly non-visible plume conditions:

EARLIEST	LATEST	MEDIAN
1980	1990	1985
____	____	

7. Coal gasification/desulfurization:

EARLIEST	LATEST	MEDIAN
1979	2025	2002
____	____	

8. Development of a pollution-free power source for individual

transportation (hydrogen fuel cells, solar, i.c., etc.)

EARLIEST	LATEST	MEDIAN
1980	2050	2015
____	____	

9. Correlation of ambient levels with stack emissions so that air quality monitoring can be used to indicate allowable atmospheric loading:

EARLIEST	LATEST	MEDIAN
1985	2000	1993
____	____	

10. Control/removal of SO_x emissions in:

a. All stationary sources

EARLIEST	LATEST	MEDIAN
1976	2000	1988
____	____	

b. Industry

EARLIEST	LATEST	MEDIAN
1980	1995	1988
____	____	

c. Power plants

EARLIEST	LATEST	MEDIAN
1980	2100	2040
____	____	

III. General Energy/Environment

1. Widespread use of "planned community approach to urban planning, incorporating air quality aspects:

EARLIEST	LATEST	MEDIAN
1974	2025	2000
____	____	

2. Development and use of urban mass transit systems:

EARLIEST	LATEST	MEDIAN
1980	2500	2240
____	____	

3. Widespread use of hydrogen as a fuel:

EARLIEST	LATEST	MEDIAN
1990	2050	2020
____	____	

IV. Added Items

1. Use of pyrolysis for energy production from refuse:

EARLIEST	LATEST	MEDIAN
1980	2000	1990
____	____	

2. Use of wind generators for limited energy applications:

EARLIEST	LATEST	MEDIAN
1983	2000	1992
____	____	

3. Widespread electric power generation from solar energy:

EARLIEST	LATEST	MEDIAN
1985	2023	2004
____	____	

Letter of Invitation to Added Panel Members

Dear

For the past several months we have been conducting a Delphi projection of future developments in air pollution control. The attached list was prepared by a panel of experts from the air pollution research/control community, with expected earliest and latest estimates for the realization of each event.

I would like to invite you to participate in this venture by expressing your reaction to the dates projected by other panel members. If you disagree with either the EARLIEST or the LATEST date for any event, cross it out and enter on the line below it the date you think is more realistic for the attainment of that event.

Please return the completed document to me as soon as possible (by September 16) and I will tabulate all dates and inform you of the final results. The projections of individual panel members will remain anonymous, of course.

Thank you for your cooperation.

Very truly yours,

John M. Turner

APPENDIX F

DELPHI PANEL PARTICIPANTS

1. Mr. Donald A. Brown, P.E.
   Chief Engineer
   Dawkins and Associates, Incorporated
   Orlando, Florida

2. Mr. Robert H. Collom, Jr.
   Chief, Air Quality Control Section
   Georgia Department of Natural Resources
   Atlanta, Georgia

3. Mr. Donald C. Hunter, P.E.
   Chief, Manual Air Monitoring Section
   New York State Department of Environmental Conservation
   Albany, New York

4. Dr. Roy O. McCaldin
   Engineering Consultant
   Tucson, Arizona

5. Dr. William J. Moroz
   Director, Center for Air Environment Studies
   Pennsylvania State University
   University Park, Pennsylvania

6. Dr. Lewis H. Rogers
   Executive Vice President
   Air Pollution Control Association
   Pittsburgh, Pennsylvania

7. Dr. Robert S. Sholtes
   Southern Environmental Associates
   Gainesville, Florida

8. Mr. Stanley F. Sleva
   Chief, Air Pollution Training Institute
   U.S. Environmental Protection Agency
   Research Triangle Park, North Carolina

9. Mr. Robert Stockman
   Executive Assistant Director
   State of Washington Department of Ecology
   Olympia, Washington

10. Dr. Paul Urone
    Professor, Department of Environmental Engineering
    University of Florida
    Gainesville, Florida

11. Mr. David M. Benforado, P.E.
    Environmental Engineering and Pollution Control Department
    3M Company
    St. Paul, Minnesota

12. Mr. Daniel Bienstock
    Research Supervisor, Energy Conversion
    U. S. Bureau of Mines
    Pittsburgh, Pennsylvania

13. Dr. A. J. Haagen-Smit
    Professor, Division of Biology
    California Institute of Technology
    Pasadena, California

14. Mr. I. Arthur Hoekstra, P.E.
    Director, Division of Air Pollution Control
    County of Erie
    Buffalo, New York

15. Mr. Alex Kaiser
    Director, Power Plant Engineering and Environmental Planning
    Tampa Electric Company
    Tampa, Florida

16. Mr. John S. Lagarias, P.E.
    Manager, Industrial Environmental Control
    Kaiser Engineers
    Oakland, California

17. Mr. Benjamin Linsky
    Professor of Sanitary Engineering
    West Virginia University
    Morgantown, West Virginia

18. Mr. Joseph Lukacs, P.E.
    President
    Western Research and Development, Limited
    Calgary, Alberta, Canada

19. Mr. Joseph Palomba, Jr.
    Assistant Director, Air Pollution Control Division
    Colorado State Department of Health
    Denver, Colorado

20. Mr. Harold J. Paulus
    Professor, School of Public Health
    University of Minnesota
    Minneapolis, Minnesota

21. Mr. Victor H. Sussman
    Director, Stationary Source Environmental Control
    Ford Motor Company
    Dearborn, Michigan

22. Mr. John W. Walton, P.E.
    Assistant Director, Engineering Program
    Division of Air Pollution Control
    Tennessee Department of Public Health
    Nashville, Tennessee

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BIOGRAPHICAL SKETCH

John Miller Turner was born in Pennsylvania and attended schools in Pennsylvania and Florida.

After serving in the U. S. Navy, he attended the University of Florida. He graduated in 1958 with the degree Bachelor of Chemical Engineering and accepted employment with a large paper manufacturing firm. He progressed through a number of engineering and supervisory positions to become Senior Project Engineer.

In 1967, he returned to the University of Florida and in 1968, received the degree Master of Education. He accepted an appointment to the faculty of Santa Fe Community College with responsibility for designing and implementing the nation's first two-year air pollution control technology training program. Continuing his graduate studies on a part-time basis at the University of Florida, he received the degree Master of Science in Engineering in 1970.

In 1971-72, he was the Director of a USOE contract with Santa Fe Community College to prepare a model curriculum guide for air pollution control technology programs. The guide was published in 1973.

He is presently Director of Planning and Research for Santa Fe Community College in Gainesville, Florida.

He is married to the former Elaine Syfrett of Chipley, Florida and has a daughter, Jennifer, and a son, David.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

James L. Wattenbarger, Chairman
Professor of Education

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

James W. Hensel
Professor of Education

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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This dissertation was submitted to the Graduate Faculty of the College of Education and to the Graduate Council, and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

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